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Pole Strength Tests

RICHARD C. EGGLESTON, Bell Telephone Laboratories, Inc.*
Murray Hill Laboratory, Murray Hill, New Jersey

AT THE PRESENT TIME there are more than eighteen million poles in the lines of the Bell System. If laid end to end they would encircle the earth four times. It is to be expected, therefore, that public utility engineers would have an interest in any information relating to such an important item of outside plant material. This paper describes strength tests made on 395 poles and discusses the results. Conclusions are drawn concerning the effect of greensalt and pentachlorophenol treatments on the bending strength of southern pine poles; and also concerning the effect of such factors as kiln-drying, steaming, moisture content and knots.

The tests were made in 1939, 1940, 1941, and 1946 at the Chester Field Station of the Bell Telephone Laboratories. The kind and number of poles tested in each of these years were as follows:

Kind of Poles	Number of Poles					
	1939	1940	1941	1942	1946	Total
Untreated southern pine	20					20
Creosoted southern pine	26	29	27			82
Pentachlorophenol southern pine			3	20	20	43
Greensalt and Celcure-southern pine	49	88	89			226
Greensalt-lodgepole pine, Douglas fir and western red cedar	—	15	9	—	—	24
Total	95	132	128	20	20	395

The primary purpose of the tests was to determine whether salt treatment, or kiln drying or penta treatment affected the strength of the poles. This paper describes the tests and discusses the results.

THE TEST POLES

The quantity, treatment, plant from which supplied and the year of production of the test poles are shown in the following table:

In portions of the text and in the tables that follow, the poles from Plant A will be referred to as A1937 poles, or A1938 poles, or A1940 poles; those from Plant B as B1938 poles; those from Plant C as C1940 poles; those from Plant D as D1941 poles; and those from Plant E as E1942 poles. A more detailed history of these groups of poles from the date of production to the date of test is given in Appendix 1. The poles varied in length from 18 feet to 40 feet and in class from 1 to 10.

Number Of Poles		Plant Designation	Year Produced
6	Creosoted (expansion bath)	A	1937
10	Untreated	B	1938
10	Untreated	A	1938
56	Creosoted	B	1938
20	Creosoted-kiln dried	C	1940
13	Penta-petroleum	D	1941
30	Creo-penta and creosoted	E	1942
143	Greensalt and Celcure	A	1938
107	Greensalt	A	1940
395			

Upon arrival at the Chester Field Laboratory, all of the poles were laid side by side on skids for measurement and subsequent disposition.

PRE-TEST MEASUREMENTS

Circumference and knot measurements were made on all but 40 of the test poles. The diameter of each knot over 1/2 inch and its location on the surface of the pole, with relation to the butt and to the longitudinal center line of the face of the pole, were measured and recorded on a sheet prepared for the purpose. On the same sheet the circumferences at intervals of two feet from the butt to the top of the pole were also recorded. The technique used in making these measurements is described in Appendix 2.

CONDITIONING

Following measurement, the test poles were either placed in the butt-soaking shed, or set in the ground, or placed in a pole drying rack, or left on the skids.

Butt Soaking

All of the poles in the 1939 tests were butt

*Now with Signal Corp Laboratory, Department of the Army.

soaked[1] in order to simulate average service conditions, where the moisture content of the butt section of a pole is at or above fiber saturation, and also to eliminate the necessity for attempting any correction of the test results for moisture. The poles were piled horizontally in a shed with peat and sphagnum moss packed around the "below ground" sections. A water sprinkler was installed across the top of the shed and this sprinkler was kept in almost continuous operation from May 19 until September 14, 1939 when the 1939 tests were completed. A photograph of the test poles in the butt-soaking shed is shown in Fig. 1.

On or before May 19, 1939, twenty B1938 creosoted poles and forty-nine A1938 salt-treated poles were placed in the shed on June 28, 1939. As the untreated poles were broken on July 17 and 18, 1939, they were subjected to only about 20 days of butt soaking. The 69 treated poles were broken between September 5 and September 14, 1939 and hence were subjected to butt soaking for approximately 16 weeks.

Setting in Ground and Racking

Subsequent to the completion of the 1939 tests, the question arose as to what effect the soaking of the butts had on the strength of the poles. To answer this question, it was decided with respect to the poles to be broken in 1940, and which were then on skids, to wet the butts of some by setting them in the ground to normal setting depths; to place others upright in a drying rack to insure uniformity in the drying process throughout the pole's length; and also to include in the 1940 tests some of the creosoted B1938 poles that had already been set in the ground in July, 1939. A photograph of one of the drying racks used is shown in Fig. 2.

Summary of Conditioning

In a table at the end of Appendix 1 is shown the approximate length of time the test poles were on skids, in the butt-soaking shed or in the ground, and in the drying racks. Some of the 1940 test poles were neither grounded nor racked but taken directly from the skids and broken. For convenience of reference, such poles will be referred to hereafter as "skid poles"; the poles that were set in the ground as "ground poles"; and those that were conditioned in a drying rack as "rack poles."

As previously stated, all of the 1939 test poles were butt-soaked. About a third of the 1940 test poles were ground poles and the balance rack or skid poles. Only 10 of the 1941 test poles were ground poles. The rest were rack poles. All of the 1942 test poles were skid or rack poles. All of the 1946 test poles were ground poles.

In the text and tables that follow, the poles butt-soaked and the poles set in the ground are referred to as "wet poles" (viz. above fiber saturation), and the poles that were conditioned in the drying racks or on skids are referred to as "dry poles."

METHOD OF TEST

Layout

A drawing of the field layout for conducting the tests is shown in Fig. 3. A photograph of the layout is shown in Fig. 4. For convenience of reference, the principal features of the layout have been denoted on the drawing by capital letters. The butt of the pole to be tested was placed in the crib (A) with its top resting on the railroad rail (E). The crib was made of concrete reinforced by 5/8 inch round deformed steel bars. The details of its construction are shown in Fig. 5 and a photograph of the crib with a pole in place is shown in Fig. 6.

Placing Pole

After the pole was placed, it was rotated until its gained side was up and shifted longitudinally until its groundline[2] coincided with the front face of the crib. The pole was then secured firmly in place by means of the oak wedges and steel channels shown in the drawings (Figs. 3 and 5), the wedges to prevent appreciable lateral movement and the channels to prevent vertical movement. Between the wedges and the pole was placed a Douglas-fir saddle, with rounded edges and a concave surface on the pole side to prevent scoring or other injury to the pole at the groundline.

Pulling Line

In the 1939 tests a short length of chain was looped around the pole at two feet from the top and a large swivel was hooked into the ends of this chain. To the ring end of the swivel a 90-foot length of winch line was shackled when 30-foot poles were tested and shorter lengths of winch line for shorter poles. The other end of the winch line was shackled to a 5,000-pound Chatillon dynamometer. To the opposite end of the dynamometer another large swivel was shackled and hooked into one of a pair of double blocks. The anchorage for the double blocks was the truck (H) (Fig. 3), on which a power

[1] Except Test Pole No. 1, on which a temperature study was being made until it was tested.

[2] The groundline distance from butt used in these tests were in accordance with Bell System standards, viz: 3-1/2 feet for 18 foot poles; 4 feet for 20 foot and 22 foot poles; 5 feet for 25 foot poles; 5-1/2 feet for 30 foot poles; 6 feet for 35 foot and 40 foot poles.

winch was mounted to provide the pull on the pole under test. A pair of triple blocks was attached in the running line of the double blocks. The truck was also the anchorage for the triple blocks; and the running line of these blocks was wound on the winch drum. The arrangement of this tackle is shown diagrammatically at (G) (Fig. 3). The purpose of this combination of blocks was to reduce the speed of pull to the desired minimum.

On account of its tendency to twist, some difficulty was experienced with the winch line used in the 1939 tests as the pulling line between the pole and the dynamometer. Accordingly, in the 1940 and subsequent tests, 3/8 in. "H.C.H. T." steel chain was substituted for the winch line with satisfactory results. A chain length of 60 feet was used on 30-foot and longer poles and a length of 35 feet on 25-foot and shorter poles. It was also found desirable to install swivel hooks on each end of the dynamometer as shown in Fig. 7.

Dynamometer Support

In the 1939 tests, as pull was applied to a pole under test, the dynamometer slid along planed planks laid lengthwise on a ladder resting on the ground. In a few instances when sudden breaks occurred, the dynamometer was overturned and slightly damaged. In order to minimize the possibility of injury, the instrument was supported during the 1940 and all subsequent tests in a sled-like cradle which slid along the ladder rungs as pull was applied to the pole. A photograph of this support is shown in Fig. 7.

The wooden screens shown at F (Fig. 3) were provided to protect the man reading the dynamometer from possible breaks in the pulling line.

Load

As previously mentioned, the pull on the test poles was applied through a power winch mounted on a truck. By pretest trials, determinations were made of the required rates of winch speed to produce the desired rates of pole deflection. The rates employed in terms of inches of deflection of the load point per minute were approximately as follows:

3.5 inches per minute for Class 4 and larger 30-foot poles, and all 25-foot and shorter poles;

5.5 inches per minute for Class 5 and smaller 30-foot poles, and Class 4 and larger 35-foot poles;

8.0 inches per minute for Class 5 and smaller 35-foot poles, and all 40-foot poles; and

2.0 inches per minute for all pole tops.

The basis for these rates of speed is shown in Appendix 3.

A stake was set in the testing field to mark the winch position for each different length of pole tested. The location of three of these stakes is shown in Fig. 3 and the basis upon which they were located is discussed in Appendix 4.

Measurement of Pole Movement

At C (Fig. 3) is shown a datum rail, which is parallel to the axis of the pole shown in the crib (A - Fig. 3). A scale was mounted on this rail for measuring the movement of the load point of the test pole towards the butt. A steel tape was stretched across the scale to the load point, for measuring the deflection of the pole top. The man reading the tape and scale was protected by the barricade shown at D (Fig. 3).

At B (Fig. 3) is shown a small shelf on which a short scale was mounted. A piece of lattice with a hole in one end and a pointer near the other end extended from the shelf to the pole under test. The hole end of the lattice was tacked to the pole as close to the groundline as possible. The pointer at the other end extended over the scale. The purpose of this installation was to measure the movement of the test pole at the groundline.

TEST PROCEDURE

Measurements

Before any load was applied, an initial reading was taken (1) on the tape to one edge of the datum rail scale, (2) on the datum rail scale at the point where one edge of the tape crossed, and (3) on the scale at B (Fig. 3) where indicated by the pointer on the lattice. By means of a T-square, the tape was kept as nearly as possible perpendicular at all times to the datum rail. These initial readings were recorded as follows on Data Sheet 1: the tape readings in Column "t"; the scale readings in Column "s"; the lattice scale readings in Column "g".

At this time also the following measurements were made and recorded on Data Sheet 1:

(1) Actual distance from butt of test pole to groundline (i.e. point of support). (2) Distance from groundline to load point (i.e. a distance equal to the nominal length of the pole, minus its standard setting depth, minus 2 feet). A crayon mark was made at the load point to show where the pulling line chain should encircle the pole. (3) Distance from load point to top. (4) Circumferences to the nearest tenth inch of the groundline, load point and top.

A sample Data Sheet 1 is shown in Appendix 5.

The difference between the initial and subsequent tape readings ("t") measures the deflection of the pole top, or more specifically, the

movement of the point of tape attachment (point of load) in a direction perpendicular to the datum rail. Similarly, the difference between the initial and subsequent scale readings ("s") measures the movement of the load point toward the pole butt in a direction parallel to the datum rail. The lattice readings ("g"), which measure the movement of the pole at the groundline (crib bearing point), would be needed to correct the deflection readings, if a calculation of modulus of elasticity were made.

Load Application

The load was applied continuously until the pole failed. At every 200-pound increment on the dynamometer, a whistle was blown. At each blast of the whistle, "t", "s", and "g" readings were made and recorded (Data Sheet 1) until the pole was broken. The maximum load shown by the dynamometer was also recorded. After breaking, an estimate was made of the location of the break, and the distance from this estimated location to the point of where the load was measured and recorded. Photographs of many of the breaks were taken. Those showing typical examples of the kind of breaks encountered are shown in Fig. 8.

Density and Moisture Data

Discs approximately one inch thick for use in determining moisture content and specific gravity were cut from the poles soon after removal from the testing crib.

In the 1939 tests, two discs were cut from each pole: one from the section one foot below the groundline and the other from above but as close as practicable to the break. These discs were subsequently split into four approximately equal sectors. From each sector was cut a smaller sector, or wedge, free from knots and having an arc length of approximately two inches. When the cross section was knotty only three wedges were cut. Each wedge was then split into the following pieces: outer 1/4-in. zone; next 1/4-in. zone; next 1/2-in. zone; next 1/2-in. zone; next 1/2-in. zone; next 1/2-in. zone; remainder of sapwood; heartwood.

Corresponding pieces from each of the wedges were combined and moisture content, specific gravity and the preservative content, if creosoted, were determined from the same sample. All moisture content determinations were made by toluol extraction. The results were recorded on Data Sheet 3. A sample Data Sheet 3 is shown in Appendix 5.

In the tests of 1940 and 1941, the procedure with respect to cutting discs from the test poles for density and moisture content determinations was the same as in the 1939 tests for both creosoted and salt treated ground poles; except that the zoning for the salt poles was as follows: outer 1/4-in. zone; next 1/2-in. zone; next 3/4-in. zone; next 3/4-in. zone; remainder of sapwood; heartwood.

The procedure for the rack and skid poles, however, except the B1938 poles, was to cut only one disc at the midpoint. This change in procedure was made on the basis that the longitudinal distribution of moisture in the dry poles would not be sufficiently non-uniform to warrant the extra work of cutting two discs from each pole. Two discs, however, were cut from most of the B1938 rack poles.

In the 1942 tests the zoning from the D1941 poles was the same as in the 1939 tests, but only above-break discs were cut from each pole. No discs were cut from the E1942 poles. In the 1946 tests, which included E1942 poles only, discs were cut from one foot below the groundline only. The zoning was as follows: outer 1/4-in. zone; next 1/2-in. zone; next 1/2-in. zone; next 1/2-in. zone; remainder of sapwood; heartwood.

Top Testing

After the poles were broken in the 1940, 1941 and 1942 tests, all tops of sufficient length to test (13 feet and longer), except a few which were retained for test plot installation, were placed in the testing crib and broken to determine the relation between the modulus of rupture of the pole as a whole and its top.

All tops tested were grouped into two length classes: tops 13 to 15 feet long; and tops 15 feet and longer. The load point for the 13 to 15-foot class was arbitrarily fixed at 10 feet from the groundline, and for the 15-foot and longer class at 12 feet from the groundline.

The methods employed in the top testing were the same as used for the full-length poles, except (1) that, in order not to minimize the weakening effect of the gains by placing the top in the testing crib so that its gained side would be up, half the tops were tested with the gained side in tension and half with the gained side in compression; and except (2) that the winch positions were fixed as follows (see also Appendix 4):

Length of Section Under Test	Coordinates of Winch Position	
	Distance from face of testing crib	Distance from long axis of test section *
13 to 15 ft.	9 ft. - 9 in.	91 ft.
15 ft.+	11 ft. - 8 in.	105 ft.

* 7 times length of section

COMPUTATION OF RESULTS

Load Correction

When necessary, corrections in observed dynamometer readings were made from numerous dynamometer calibrations made before, during, and after the tests. A record of these calibrations was filed with the test data sheets.

Lever Arm Corrections

The corrections made in the observed final "S" readings are described in Appendix 6.

Strength Calculations

The modulus of rupture for each pole and pole top broken was calculated by the method shown in Appendix 7. No calculations were made of the maximum fiber stress at break, or other strength values, although the test data sheets contain the information required for such calculations should they ever be desired.

RESULTS

Group average results for each series of tests, including a summary for the southern pine test poles, are shown in Table 1. The results of the tests of the lodgepole pine, Douglas-fir and western red cedar poles are also recorded in Table 1 as a matter of record. Because of the small number of poles of these latter species tested the results shown have little, if any, significance and no further reference will be made to them. Information, however, from the individual data sheets for these poles was included in the tabulations that follow under the captions "Knots" and "Location of Breaks."

The Table 1 data were taken from tabulations of the results shown on the pole data sheets. Because of the enormous amount of printing that would be involved, the tabulations are not presented. With reference to the summary at the end of Table 1 it will be noted that ten each of the "creosoted-kiln dried-wet" and the "creosoted-kiln -dried-dry" poles are listed, whereas, in the body of the table, 15 of the poles are correctly listed as ground poles and 5 as rack poles. The 5 (C1940) ground poles, however, were at or below fiber saturation at the time of test, and consequently are classed as dry in the summary.

In Table 2 are shown the summary values listed at the end of Table 1 for all of the southern pine poles tested (except the 20 untreated poles, the 6 expansion-bath poles and the 43 D1941 and E1942 poles) together with modulus of rupture values corrected to a specific gravity of 0.48 (the approximate average for all of the southern pine poles) on the assumtpion that modulus of rupture varies by the one and one-quarter power of the specific gravity. The six expansion bath poles were broken solely for the purpose of trying out the testing equipment, and are listed in Table 1 merely as a matter of record. The other southern pine poles omitted from Table 2 will be discussed later.

DISCUSSION

Before beginning a discussion of the test results it seems desirable to make the following statements of fact concerning the specific gravity values recorded in Table 1.: (1) Those recorded in the "Pole" column are averages of the gravities determined from sections taken from both above break and below break. (2) Those recorded in the "Pole Top" column are above break gravities for the pole. (3) Wherever, pole specific gravities are shown in the text that follows, the values were taken from the "Pole" column, except that, where no value is shown in that column, the above-break (pole) gravities in the "Pole Top" column have been used.

In the results shown in the summary at the end of Table 1 it will be noted that considerable differences in specific gravity and moisture content exist between the several groups of poles. These differences must of course be taken into account in any strength comparisons made. As previously indicated, a specific gravity correction is shown in the Table 2 results. With respect to this correction, since it is a fact that the modulus of rupture of wood varies with some power of its specific gravity, the correction made in Table 2 is at least correct in principle. Extensive work by the U. S. Forest Service[3] shows that the modulus of rupture of wood in general varies by the one and a quarter power of its gravity.

From the results shown in Table 2 the following strength comparisions were made: (1) Greensalt and Celcure treated vs. creosoted poles; (2) Kiln dried vs. non-kiln dried creosoted poles; (3) Fifty-fifty penta-creo treated vs. straight creosoted poles; (4) Steamed vs. unsteamed poles; (5) Wet vs. dry poles.[4]

It should be noted in these comparisons and subsequent discussions that the term "strength" related solely to modulus of rupture, or fiber strength in bending.

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[3] "The Relation of Shrinkage and Strength Properties of Wood to its Specific Gravity" by J. A. Newlin and T. R. C. Wilson, U.S. Dept. Agr., Bul. 676.

[4] Except where otherwise noted, by "wet" poles is meant the "BS" (viz. butt soaked) poles or the "ground" poles. By "dry" poles is meant poles that were conditioned in the drying racks or on skids prior to testing.

Greensalt and Celcure Treated vs. Creosoted Poles:

Both in the testing and in the tabulation of the results, it appeared that the salt-treated A1940 poles were stronger than the salt-treated A1938 poles. To check this impression, the average modulus of rupture was determined for both the A1940 and the A1938 unsteamed dry poles, which is the only group containing both vintages. The average for the eighty-three A1940 poles was 9,946 psi. The average for the fifty-six A1938 poles was 14.5 percent lower, or 8,505 psi. This fact should be kept in mind in the comparisons that follow:

The actual and corrected modulus of rupture values for the steamed poles of Table 2 follow:

Steamed Wet poles	Creosoted	S1938 Salt-Treated
Number of poles	15	18
Average overall specific gravity	.45	.49
Average overall moisture content, percent	48	75
Average actual modulus of rupture, psi	6630	6190
Corrected modulus of rupture, psi	7200	6000
Relative actual strength	100	93
Relative corrected strength	100	83
Steamed Dry Poles		
Number of poles	11	14
Average overall specific gravity	.45	.47
Average overall moisture content, percent	19	17
Average actual modulus of rupture, psi	7320	7630
Corrected modulus of rupture, psi	7900	7800
Relative actual strength	100	104
Relative corrected strength	100	99

Both the actual and corrected results in this comparison would seem to indicate that the steamed salt-treated wet poles were weaker. The actual results in the steamed dry group, however, would indicate slightly greater strength for the salt-treated poles, and substantially no difference in strength as measured by the corrected results.

A similar comparison for the unsteamed poles follows:

Unsteamed Wet Poles:	Creosoted Air Seasoned	Creosoted Kiln Dried	A1938 Salt Treated
Number of poles	25	10	55
Average overall specific gravity	.45	.52	.51
Average overall moisture content, percent	43	28	40
Average actual modulus of rupture, psi.	7830	8950	7760
Corrected modulus of rupture, psi.	8500	8100	7200
Relative actual strength (including kiln dried)	100		95
Relative corrected strength (including kiln dried)	100		86
Relative actual strength (excluding kiln dried)	100		99
Relative corrected strength (excluding kiln dried)	100		85
Unsteamed Dry Poles:			
Number of poles	5	10	139*
Average overall specific gravity	.46	.53	.48
Average overall moisture content, percent	22	21	17
Average actual modulus of rupture, psi.	8240	9660	9340
Corrected modulus of rupture, psi.	8900	8500	9300
Relative actual strength (including kiln dried)	100		102
Relative corrected strength (including kiln dried)	100		108
Relative actual strength (excluding kiln dried)	100		113
Relative corrected strength (excluding kiln dried)	100		104

*56 - A1938 poles and 83 - A1940 poles.

In the unsteamed wet pole comparison of the actual results there is very little difference between the creosoted and salt-treated poles whether the kiln-dried poles are included or excluded; but the corrected results would indicate the creosoted poles to be stronger. In the unsteamed dry group, however, whether the kiln-dried poles are included or excluded, both the actual and corrected results show the salt-treated poles to be stronger.

This unsteamed dry pole comparison is thought to be more reliable than any of those previously made since it involves both the A1938 and the A1940 salt-treated poles. It should be noted, however, that since the average moisture content of the salt treated poles is 4 percent lower than for the creosoted poles, it cannot be claimed with certainty that the greater strength of the salts is due wholly to the salt treatment. In the writer's opinion, however, some of the greater strength is due to the salt treatment.

The Bell System standard creosoted southern pine pole is a steamed pole. The ultimate standard greensalt pole may be an unsteamed pole. If the strength of the fifty-five A1938 poles and the one hundred thirty-nine A1938 and A1940 poles included in the foregoing unsteamed group were compared respectively with the 15 wet and 11 dry creosoted poles of the steamed group, the results would show the salt treated poles stronger than the creosoted poles as follows: 17 to 28 percent stronger based on actual results; 0 to 18 percent stronger based on corrected results.

But here again it is not possible to say how much of the strength increase is due to the salt treatment. It can be said, however, that, other factors being equal, the strength of the unsteamed greensalt southern pine pole will exceed that of the standard creosoted pine pole by at least the loss due to steaming; and that there would be some gain in strength over the steamed creosoted pole even though the greensalt pole were also conditioned by steaming.

Kiln-Dried vs. Non-kiln-Dried Creosoted Poles

Both the actual and corrected figures of Table 2 indicate that the kiln-dried poles were stronger than the steamed creosoted poles. The actual figures indicate that the kiln-dried poles were also stronger than the unsteamed creosoted poles; but the corrected figures indicate they were somewhat weaker. When the relatively large density difference is considered, a fair conclusion is that the kiln-dried poles were stronger than the steam conditioned creosoted poles, but no stronger, if indeed as strong, as the air-seasoned creosoted poles.

Fifty-Fifty Penta-Creo vs. Creosoted Poles

At Plant E in 1942, each of 15 poles 40 feet in length was measured and cut in two, making 15 butt-cut poles and 15 top-cut poles each 20 feet long. All 30 of these E1942 poles were steam conditioned. All of the odd numbered butt-cut poles and all of the even numbered top-cut poles were pressure treated with creosote. All of the even butts and odd tops were pressure treated with a pentachlorophenol-petroleum-creosote solution. All 30 poles were then shipped to Chester for test. Since the two groups were considered to be matched, moisture content and specific gravity determinations were made on only three of the poles. In these three the average moisture content was 70 percent and the average specific gravity was 0.46. No strength correction for gravity was made for any of the 30 poles. Computation of the Table 1 values for these E1942 poles shows an average modulus of rupture of 6,465 psi. for the creosoted group, and 6,389 psi. for the creo-penta group.

It is concluded that there was no significant difference in strength between the two groups and that the fifty-fifty penta-creo treatment has no effect on the strength of southern pine poles.

With respect to the penta-petroleum (no creosote) D1941 poles listed in Table 1, the low strength value was probably due to severe steaming and not to the penta treatment.

Steamed vs. Unsteamed Poles

The ratio of the strength of the steamed to the unsteamed poles is shown in the tabulation that follows. The actual strength figures of Table 2 were used in this comparison since the density differences are small. The kiln-dried, and the 1940 greensalt poles were not included as there were no comparable groups with which to compare them.

The 20 untreated poles were not included because some of them showed evidence of decay infection at the time of test.

These data in the following table indicate that the steaming processes reduced the strength of the southern pine test poles about 16 percent. This confirms the findings of Buckman, Hatt, and Hosford.[5]

[5] "Effect of Steaming on the Strength of Southern Yellow Pine," by Stanley J. Buckman and Louis W. Rees, pg. 264 of Proceedings American Wood-Preservers' Association, 1938.

"Experiments on the Strength of Treated Timber", by W. K. Hatt, U. S. Department of Agr. Forest Service Circular 39, 1906.
"Mechanical Strength of Southern Yellow Pine Poles" by Roger F. Hosford, American Telephone and Telegraph Company, Department of Development and Research Bulletin No. 190, April 13, 1925.

No. of Poles	Group	Density	Moisture Content	Modulus of Rupture Steamed	Modulus of Rupture Unsteamed	Ratio % Steamed to Unsteamed
15	Creo-Wet (B1938))					
15	Creo-Wet (A1942))					
15	Creo-Penta-Wet (A1942))	.45	35	6350		
13	Penta-Pet*-Wet (D1941))					
25	Creo-Wet (B1938)	.45	43		7830	81
11	Creo-Dry (B1938)	.45	19	7320		
5	" " "	.46	22		8240	89
18	Salt-Wet (A1938)	.49	75	6190		
55	" " "	.51	40		7760	80
14	Salt-Dry (A1938)	.47	17	7630		
56	" " "	.47	16		8510	90
				Weighted Average		84

*Penta-Petroleum

Wet vs. Dry Poles

The ratio of the strength of the wet to the dry poles is shown in the following tabulation. The corrected strength values of Table 2 are used in this comparison because of the density differences in the salt treated groups. The dry 1940 salts were not included since there was no wet group of 1940 salt-treated poles with which they might be compared.

No. of Poles	Group	Moisture Content	Modulus of Rupture Wet	Modulus of Rupture Dry	Ratio % Wet to Dry
15	Creo-Steamed	48	7200		
11	" "	19		7900	91
25	Creo-Unsteamed	43	8500		
5	" "	22		8900	95
10	Creo-Kiln Dried	28	8100		
10	" " "	21		8500	95
18	Salt-steamed	75	6000		
14	" "	17		7800	77
55	Salt-Unsteamed	40	7200		
56	" "	16		8700	83
			Weighted Average		86

These data indicate that the wetting of the butts of the southern pine poler prior to testing by butt soaking or setting in the ground resulted in a strength loss of about 14 percent.

The preceding five strength comparisons were, as previously mentioned, based on the results shown in Tables 1 and 2. The discussions that follow are based on a study of the individual test data sheets.

Knots

In the following tabulation is shown the number and percent of poles and pole tops that broke at a maximum single or maximum group of knots. The tabulation is based on all the poles and tops tested, except 40 poles and one pole top on which knot measurements were not made.

Series	Number in Test	Breaks at Max. Single Knots Number	Breaks at Max. Single Knots Percent	Breaks at Max. Groups of Knots Number	Breaks at Max. Groups of Knots Percent
		POLES			
1939	89	2	2.2	4	4.5
1940	132	4	3.0	2	1.5
1941	124	0	0	4	3.2
1942	10	0	0	0	0
			1.7		
Overall	355	6		10	2.8
		POLE TOPS			
1940	103	7	6.8	9	8.7
1941	69	2	2.9	7	10.0
1942	10	1	10.0	0	0
Overall	182	10	5.5	16	8.8

It will be noted that less than three percent of the pole breaks and less than nine percent of the pole top breaks were at maximum knot locations. The rest of the breaks were so far removed from the locations of the maximum knots that it may be assumed that such maximum knots had little, if any, effect on the strength of the poles. In Fig. 9 is shown the average relationship between the points of break and the location of the maximum single and maximum group of knots in all the poles included in the tabulation, except the ten poles and pole tops tested in 1942.

This figure and the foregoing tabulation, however, do not present a complete picture of the relationship between breaks and knots, since many of the breaks occurred at single knots and groups of knots having diameters or sums of diameters less than the permitted maxima. Examination of the individual data sheets for the southern pine poles shows that more than a fourth of the poles and more than a third of the pole tops broke either at single knots or at knot whorls. The average sizes of the knots at which these breaks occurred were as follows:

	Average diameter single knot (inches)	Average sum of diameters (inches)
Poles	1.0	3.7
Pole tops	1.4	4.0

Thus while it is true that the strength of poles is very little affected by the maximum knots permitted under the specifications, occurring as they do in the upper part of the pole, it cannot be assumed that knots in general have no effect; for they unquestionably do. Even knots as small as one-half inch in diameter have some effect. How much effect such knots have, or the effect of such knots as compared with larger knots, is not known. All that can be said in this connection is that small knots occurring either singly or in groups in the lower third of the pole appear to be more damaging than knots of the permitted maximum sizes in the upper third of the pole.

Pole Tops

The relation of the strength of the southern pine pole tops to the strength of the poles from which the tops were cut is shown in the following table:

No. of Poles	Treatment	Strength of Poles (%)	Strength of Pole Tops (%)
	DRY POLES		
13	Creosoted-1938	100	93.7
7	Kiln Dried-1940	100	103.7
40	Salt-1938	100	82.9
63	Salt-1940	100	82.8
123		100	85.2
	WET POLES		
15	Creosoted-1938	100	91.0
6	Kiln Dried-1940	100	105.6
10	Penta-Pet.-1941	100	92.9
18	Salt-1938	100	98.9
49		100	96.1

The "dry pole" comparison shows the strength of the pole tops to be about 85 percent of the strength of the poles from which the tops were cut. Considering the fact that the density of a pole generally decreases from the butt to the top and the fact that the top of a southern pine pole usually contains more and larger knots than the lower sections, to say nothing of the possibility of non-visible injury to the pole top during the breaking test of the pole, the strength of the tops was remarkably high. The "wet pole" comparison would indicate that, except in soils so dry that the pole butts would never reach the fiber saturation point, the strength of the top of a southern pine pole in service is probably very close to the groundline strength of the pole.

Location of Breaks (Pole tops not included)

In the tabulation that follows are shown the average distances from breaks to the groundline (viz. bearing point in the testing crib) and to butt, together with the ratio of the latter distance to the length of the pole:

No. of Poles	Length (Feet)	Distance from Break to Ground-line (Feet)	Distance from Break to Butt (Feet)	Ratio to Length (%)
40	18 to 22	1.0	5.0	25
55	25	0.9	5.9	24
247	30	3.1	8.6	29
46	35	3.6	9.6	27
7	40	3.9	9.9	25
395			Weighted Av.	28

This 28 percent average is thought to be higher than it would have been if all the poles had had wet butts, for an examination of the data for the 1940 tests, where both wet and dry poles were included, indicates that the breaks of poles with wet butts are closer to the groundline. Taking this fact into account it may be concluded that on the average a machine-shaved southern pine pole, when subjected to bending stresses only may be expected to break at a dis- from its butt equal to approximately one-fourth its length. This is considerably higher up the pole than the average breaking point for the 99 hand-shaved southern pine poles broken in the A. T. & T. Co. tests described in D. & R. Bulletin 190. In those tests the average distance above the groundline to the point of break was less than two inches, which is practically at the groundline.

In the writer's opinion the greater distance above the groundline to the point of break in the Chester tests was due in part to machine shaving; and, since breaks above the groundline generally mean that the full groundline strength of the pole is not developed, machine shaving results in some loss in bending strength. No quantitative measure of the loss can be determined from the test data; nor is the question of particular moment, since the majority of telephone pole users are of the opinion that the advantages of the shaved pole are sufficient to outweigh such strength losses as may occur.

Character of Breaks

While in a few tests the first visible evidence of failure occurred on the compression side, in the majority of the tests, the first evidence of failure was a flicking up of the fibers on the tension side. This flicking was then generally followed by a wrinkle, or buckle on the compression

side, and finally by a splintering or shattering of the fibers on the tension side. Three of the breaks observed are shown in Fig. 8.

CONCLUSIONS

On the basis of the evidence shown by these tests the following conclusions have been drawn:

(1) Greensalt treatment not only does not adversely affect the modulus of rupture of southern pine poles, but probably actually results in some increase in bending strength.

(2) A kiln-dried creosoted southern pine pole is stronger than a steam-seasoned southern pine pole (current standard pole), but no stronger, if as strong, as an air-seasoned creosoted pole.

(3) Treatment with a fifty-fifty pentachlorophenol-petroleum-creosote has no effect on the bending strength of southern pine poles.

(4) The steaming of southern pine poles results in a loss in bending strength. In these tests the loss was 16 percent.

(5) The difference in strength between poles with wet butts and dry poles would depend upon the degree of dryness of the dry poles. In these tests, the wetting of the butts resulted in a strength loss of about 14 percent.

(6) While the maximum knots permitted in a hole generally have little effect on pole strength, because of their loaction, knots in general may have a decided effect. In these tests relatively small knots, occurring both singly and in groups, were associated with the break of 33-1/3 percent of the poles and 70 percent of the pole tops.

(7) Except in soils so dry that the pole butts would not reach the fiber saturation point (e.g. in arid or semi-arid areas) the strength of the tops of southern pine poles in service is probably very close to the groundline strength of the poles.

ACKNOWLEDGEMENT

The writer has been directly concerned with the conduct of these tests, and he alone is responsible for the manner of arranging the tabulated results and discussions; but it goes without saying that the labors of my Bell Laboratories' colleagues have helped to form the reservoir of information contained in this report.

APPENDIX 1

HISTORY OF TEST POLES

Untreated Poles

Following a seasoning period of about three months, ten of the 20 untreated poles tested were shipped from Plant A to Chester late in November, 1938. They arrived at Chester on December 2, 1938. The other ten untreated poles were shipped to Chester from Plant B on Dec. 17, 1938 after about one month's seasoning. They arrived at Chester on December 28, 1938. Upon arrival at Chester the poles of both groups were laid side by side on skids, where they remained until June 28, 1939 when 19 of the 20 were placed in the butt-soaking shed described in the body of this report. The butt-soaking of these poles was continued until they were tested. The remaining pole was kept on skids until tested.

Creosoted Poles

Of the 76 creosoted poles tested, 56[6] were treated at Plant B under the supervision of J. G. Segelken about the middle of November 1938, after four month's seasoning. Of this number, 26 were steamed prior to creosote treatment; 30 were treated unsteamed. On December 17, 1938, the 56 poles were shipped to Chester. Upon arrival on December 28, 1938 they were laid out side by side on skids. On May 17 and 18, 1939, ten of the steamed and ten of the unsteamed poles were placed in the butt-soaking shed, where they remained until tested. Late in July, 1939, five of the remaining steamed poles and 15 of the remaining unsteamed poles were set in the ground, where they stayed until tested. The rest of the poles were left on the skids until late in June 1940, when they were placed upright in pole drying racks, where they remained until tested.

In addition to the 56 poles creosoted at Plant B, 20 pine poles were kiln-dried and creosoted, also under supervision of J. G. Segelken, at Plant D in the spring of 1940. These 20 poles were selected from a group of longleaf pine poles that were treated in a series of kiln-drying experiments.[7] In June 1940, the 20 poles were shipped to Chester. Upon arrival on June 24, 1940, they were laid side by side on skids. On July 11, 1940, 15 of them were set in the ground and the remaining five were placed upright in a drying rack in which position they remained until tested.

[6] Exclusive of the six expansion bath poles, which were treated at Plant A in 1937 and which arrived about January 1, 1938 at Chester, where they lay on skids until they were broken early in July, 1939, in a rehearsal to check the testing equipment and methods.

[7] Segelken, J. G. - Kiln Drying Longleaf Southern Pine Poles, Proceedings of American Wood-Preservers' Association, 1941, p. 135.

TABLE 1. Group Average Results for Each Series of Tests

No. of Poles	No. of Pole Tops	Date of Test	Description*		Average Overall Specific Gravity*		Average Overall Moisture Content+		Average Modulus of Rupture	
					Pole	Pole Top	Below Break (%)	Above Break (%)	Pole (Psi)	Pole Top (Psi)
			SOUTHERN PINE POLES							
6	0	1939	Creosoted-Expansion Bath	(A1937)	.51			45	8000	
20	0	1939	Untreated-BS	(B4A1938)	.48		55	28	7473	
10	0	1939	Creosoted-Steamed-BS	(B1938)	.44		48	28	6580	
5	4	1940	Creosoted-Steamed-Ground	(B1938)	.46	.44	47	18	6724	5913
4	3	1940	Creosoted-Steamed-Rack	(B1938)	.48	.47	19	20	7510	7117
7	5	1941	Creosoted-Steamed-Rack	(B1938)		.43		20	7211	6568
10	0	1939	Creosoted-Unsteamed-BS	(B1938)	.43		51	29	7751	
6	4	1940	Creosoted-Unsteamed-Ground	(B1938)	.45	.44	36	21	7345	6795
9	7	1941	Creosoted-Unsteamed-Ground	(B1938)	.46	.46	18	17	8249	7651
4	4	1940	Creosoted-Unsteamed-Rack	(B1938)	.46	.47	22	20	7933	7945
1	1	1941	Creosoted-Unsteamed-Rack	(B1938)		.45		20	9430	6540
5	2	1940	Creosoted-Kiln Dried-Ground	(C1940)	.53	.53	25	17	10132	10665
10	6	1941	Creosoted-Kiln Dried-Ground	(C1940)	.52	.50	28	14	8953	9830
5	5	1940	Creosoted-Kiln Dried-Rack	(C1940)		.52		18	9178	9176
3	0	1941	Creo-Penta-Steamed-Skids	(D1941)	.48			34	6033	
10	10	1942	Creo-Penta-Steamed-S&R	(D1941)	.46	.46	34	45	5794	5380
5	0	1942	Creo-Penta-Steamed-Skids	(E1942)			F.S.		5716	
5	0	1942	Creosoted-Steamed-Skids	(E1942)			F.S.		5858	
10	0	1946	Creo-Penta-Steamed-Ground	(E1942)			F.S.		6726	
10	0	1946	Creosoted-Steamed-Ground	(E1942)			F.S.		6769	
2	0	1939	Greensalt K-Steamed-BS	(A1938)	.49		66	32	6910	
3	0	1939	Greensalt S-Steamed-BS	(A1938)	.52		88	66	6793	
5	0	1939	Celcure-Steamed-BS	(A1938)	.47		95	59	5494	
3	0	1939	Greensalt O-Steamed-BS	(A1938)	.49		91	73	6180	
1	1	1940	Greensalt K-Steamed-Ground	(A1938)	.48	.48	44	20	6130	7320
2	1	1940	Greensalt O-Steamed-Ground	(A1938)	.50	.47	38	17	6135	6260
1	1	1940	Greensalt S-Steamed-Ground	(A1938)	.57	.54	49	25	6280	6940
1	1	1940	Celcure-Steamed-Ground	(A1938)	.48	.46	37	16	6450	7360
1	0	1940	Greensalt K-Steamed-Rack	(A1938)		.47		17	7210	
1	1	1940	Greensalt O-Steamed-Rack	(A1938)		.48		24	6290	5220
2	2	1940	Greensalt S-Steamed-Rack	(A1938)		.48		26	6045	5335
1	1	1940	Celcure-Steamed-Rack	(A1938)		.48		25	8730	6410
3	2	1941	Celcure-Steamed-Rack	(A1938)		.46		13	8323	6265
2	0	1941	Greensalt K-Steamed-Rack	(A1938)		.43		13	8275	
2	1	1941	Greensalt O-Steamed-Rack	(A1938)		.46		13	7940	6350
2	0	1941	Greensalt S-Steamed-Rack	(A1938)		.48		13	7545	
12	0	1939	Greensalt K-Unsteamed-BS	(A1938)	.51		47	20	7665	
4	0	1939	Greensalt K-Unsteamed-BS	(A1938)	.51		44	19	8440	
11	0	1939	Greensalt S-Unsteamed-BS	(A1938)	.50		46	23	7827	
2	0	1939	Celcure-Unsteamed-BS	(A1938)	.51		41	20	8105	
7	0	1939	Greensalt O-Unsteamed-BS	(A1938)	.51		48	21	7480	
6	4	1940	Greensalt K-Unsteamed-Ground	(A1938)	.52	.50	26	16	8238	8918
4	3	1940	Greensalt O-Unsteamed-Ground	(A1938)	.51	.51	28	16	8698	8627
5	5	1940	Greensalt S-Unsteamed-Ground	(A1938)	.50	.48	29	17	7372	7144
2	2	1940	Celcure-Unsteamed-Ground	(A1938)	.49	.47	25	15	6665	5590
2	0	1940	Greensalt K-Unsteamed-Ground	(A1938)	.48	.48	29	18	5880	
7	6	1940	Greensalt K-Unsteamed-Rack	(A1938)		.49		18	7065	6342
4	4	1940	Greensalt O-Unsteamed-Rack	(A1938)		.51		16	8285	8610
5	3	1940	Greensalt S-Unsteamed-Rack	(A1938)		.47		19	8674	7890
3	2	1940	Celcure-Unsteamed-Rack	(A1938)		.49		17	9080	8040
2	0	1940	Greensalt K-Unsteamed-Rack	(A1938)		.48		33	9125	

* * *

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TABLE 1. - Cont'd.

No. of Poles	No. of Pole Tops	Date of Test	Description*		Average Overall Specific Gravity*		Average Overall Moisture Content+		Average Modulus of Rupture	
					Pole	Pole Top	Below Break (%)	Above Break (%)	Pole (Psi)	Pole Top (Psi)
			SOUTHERN PINE POLES (Cont'd.)							
12	9	1941	Greensalt K-Unsteamed-Rack	(A1938)		.48		14	8810	6369
8	4	1941	Greensalt O-Unsteamed-Rack	(A1938)		.46		14	9403	7495
10	4	1941	Greensalt S-Unsteamed-Rack	(A1938)		.45		14	7651	7308
3	1	1941	Celcure-Unsteamed-Rack	(A1938)		.48		15	8010	5110
3	0	1941	Greensalt K-Unsteamed-Rack	(A1938)		.49		16	10143	
15	14	1940	Greensalt O-Unsteamed-Skids	(A1940)		.49		20	9283	8357
16	14	1940	Greensalt K-Unsteamed-Skids	(A1940)		.50		21	9531	8254
8	5	1940	Greensalt OK-Unsteamed-Skids	(A1940)		.48		22	9890	7820
19	12	1941	Greensalt K-Unsteamed-Rack	(A1940)		.48		16	10371	8318
18	12	1941	Greensalt O-Unsteamed-Rack	(A1940)		.48		15	10549	8052
7	6	1941	Greensalt OK-Unsteamed-Rack	(A1940)		.48		16	9671	7983
371	172									
			LODGEPOLE PINE POLES							
10	9	1940	Greensalt O,K & OK Unsteamed-Skids	(A1940)	.43			21	5836	5611
	Max. (Vis. pole of max. strength)				.46			17	8470	9090
	Min. (Vis. pole of min. strength)				.38			19	3900	3240
			DOUGLAS FIR POLES							
3	0	1940	Greensalt K-Unsteamed-Skids	(A1940)	.46			23	7150	
6	0	1941	Greensalt K-Unsteamed-Rack	(A1940)	.49			14	8837	
9	0		Greensalt K-Unsteamed-Dry	(A1940)	.48			17	8274	
	Max. (Vis. pole of max. strength)				.48			14	11550	
	Min. (Vis. pole of min. strength)				.43			23	5660	
			WESTERN RED CEDAR POLES							
2	2	1940	Greensalt OK-Unsteamed-Skids	(A1940)	.34			21	4395	4855
3	0	1941	Greensalt OK-Unsteamed-Rack	(A1940)	.32			15	5207	
5	2		Greensalt OK-Unsteamed-Dry	(A1940)	.33			17	4882	4855
	Max. (Vis. pole of max. strength)				.33			16	5520	
	Min. (Vis. pole of min. strength)				.34			21	3930	4690
			SUMMARY FOR SOUTHERN POLES							
20			Untreated-Wet	(B&A1938)	.47		55	28	7473	
6			Creosoted-Expansion Bath	(A1937)	.51			45	8000	
15			Creosoted-Steamed-Wet	(B1938)	.45		48	25	6628	
11			Creosoted-Steamed-Dry	(B1938)	.45		19	20	7320	
25			Creosoted-Unsteamed-Wet	(B1938)	.45		43	23	7833	
5			Creosoted-Unsteamed-Dry	(B1938)	.46		22	20	8236	
10			Creosoted-Kiln Dried-Wet	(C1940)	.52		28	14	8953	
10			Creosoted-Kiln Dried-Dry	(C1940)	.53		21	18	9655	
13			Creo-Penta-Steamed-Wet	(D1941)	.47		34	42	5849	
15			Creo-Penta-Steamed-Wet)Matched	(E1942)			F.S.		6389	
15			Creosoted-Steamed-Wet)Samples	(E1942)			F.S.		6465	
			Salt-Steamed-Wet							
3			Greensalt K	(A1938)	.49		59	28	6650	
5			Greensalt O	(A1938)	.49		70	49	6162	
4			Greensalt S	(A1938)	.53		78	56	6665	
6			Celcure	(A1938)	.47		85	52	5653	

* * *

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TABLE 1. - Cont'd.

Poles	Tops	Test	Description*	Average Overall Specific Gravity* Pole	Pole Top	Average Overall Moisture Content+ Below Break (%)	Above Break (%)	Average Modulus of Rupture Pole (Psi)	Pole Top (Psi)
			SUMMARY FOR SOUTHERN POLES (Cont'd.)						
			Salt-Steamed-Dry						
3			Greensalt K (A1938)	.44			14	7920	
3			Greensalt O (A1938)	.47			17	7390	
4			Greensalt S (A1938)	.48			20	6795	
4			Celcure (A1938)	.47			16	8425	
			Salt-Unsteamed-Wet						
24			Greensalt K (A1938)	.51		40	19	7789	
11			Greensalt O (A1938)	.51		41	19	7923	
16			Greensalt S (A1938)	.50		41	21	7685	
4			Celcure (A1938)	.50		33	18	7385	
			Salt-Unsteamed-Dry						
23			Greensalt K (A1938)	.48			17	8556	
12			Greensalt O (A1938)	.48			15	9030	
15			Greensalt S (A1938)	.46			16	7992	
6			Celcure (A1938)	.48			16	8545	
35			Greensalt K (A1940)	.49			18	9987	
33			Greensalt O (A1940)	.48			17	9974	
15			Greensalt OK (A1940)	.48			19	9788	
371									

NOTES: *Plant and date of treatment indicated in parentheses:

Conditioning of poles prior to tests: BS = Butt Soaked; Ground = Set in Ground; Rack = Stored in pole Rack; Skids = Stored on Skids; S&R = Some stored on Skids and some stored in pole Rack.

Creo-Penta = Treatment with pentachlorophenol-petroleum-creosote solution.

* Values shown under "Pole" are averages of above and below break gravities; values shown under "Pole Top" are above break gravities only. Where no value is shown in "Pole" column, the above break value shown in "Pole Top" column is considered to be the specific gravity of the pole.

+ Determined from same disc as gravities. With but few exceptions, only one disc (viz. above break) was cut from rack and skid poles.

TABLE 2: Summary of results showing for the southern pine poles tested both the actual average modulus of rupture values and those values when corrected to a specific gravity of 0.48.

No. of Poles	Treatment	Average Overall Specific Gravity	Average Moist. Content (%)	Modulus of Rupture Test Av. (Lbs. per Sq. In.)	Corrected
	Creosoted Poles:				
15	Steamed - Wet (B1938)	.45	48	6630	7200
11	Steamed - Dry (B1938)	.45	19	7320	7900
25	Unsteamed - Wet (B1938)	.45	43	7830	8500
5	Unsteamed - Dry (B1938)	.46	22	8240	8900
10	Kiln Dried - Wet(C1940)	.52	28	8950	8100
10	Kiln Dried - Dry(C1940)	.53	21	9660	8500
76					
	Greensalt Poles:				
18	Steamed - Wet (A1938)	.49	75	6190	6000
14	Steamed - Dry (A1938)	.47	17	7630	7800
55	Unsteamed - Wet (A1938)	.51	40	7760	7200
56	Unsteamed - Dry (A1938)	.47	16	8510	8700
83	Unsteamed - Dry (A1940)	.48	18	9950	9900
226					

Fig.1--Photograph showing the butt soaking shed. Under the cover a water sprinkler was kept in almost continuous operation.

Fig.2--Photograph of one of the drying racks.

Fig. 3--Field layout for pole strength tests.

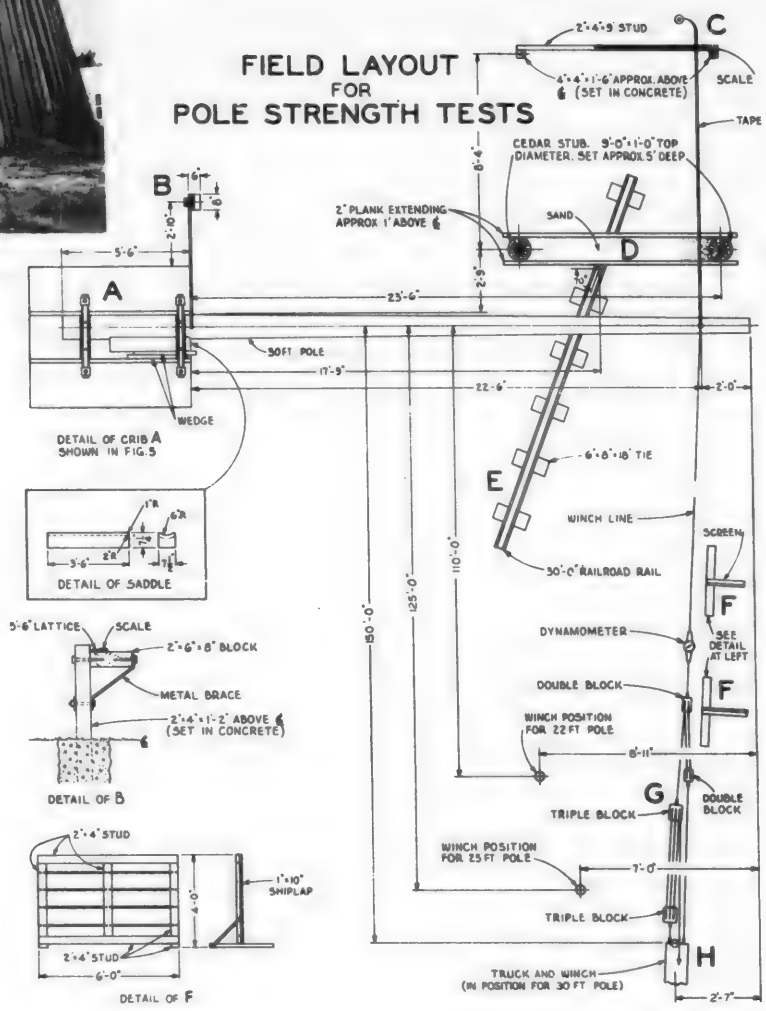


Fig. 4--Photograph showing testing field layout.

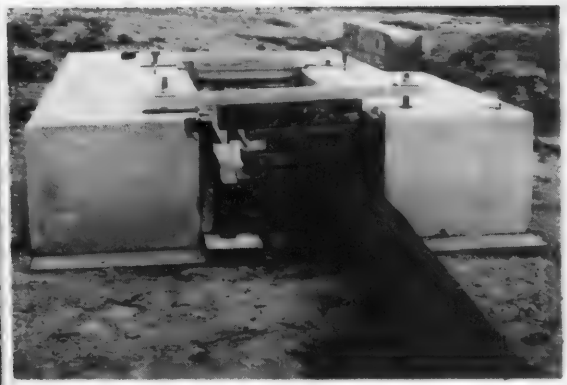
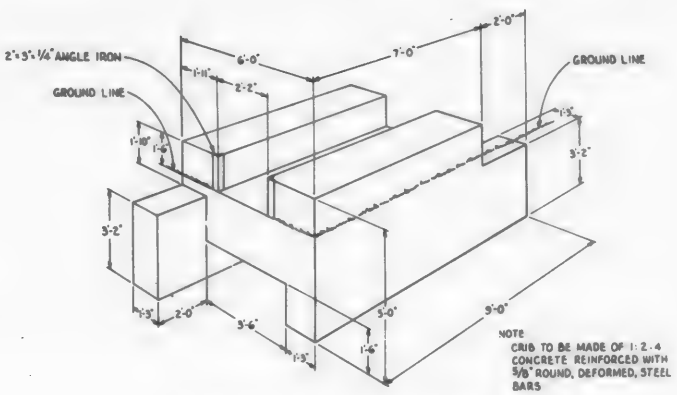
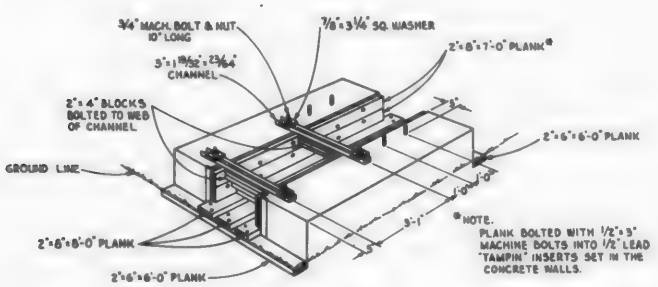


Fig. 6--Photograph showing pole testing crib with pole in place ready for test.

Fig. 5--Details for pole testing crib.



POLE TESTING CRIB



DETAILS OF CRIB FITTINGS

Fig. 7--Photograph showing sled-like cradle for dynamometer.

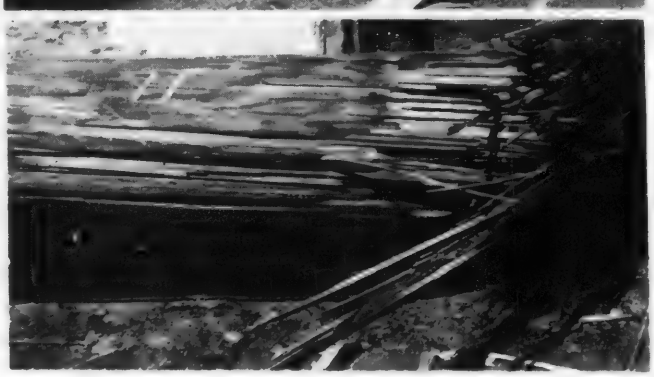


Fig. 8--Photographs showing characteristic pole breaks:
Top photograph shows a typical compression failure.
Middle photograph shows a short brash break --weak pole.
Bottom photograph shows a long splintering break--strong pole.

Pole Strength Tests

DIAGRAM SHOWING AVERAGE LOCATION OF KNOTS AND BREAKS IN TEST POLES 1939, 1940 AND 1941 TESTS (All Species)

Legend:

Maximum group of knots in any 12-inch section: ◎

Maximum single knot: ○

Groundline for poles: ——

Groundline for pole tops: - - - -

Breaks: ⩙⩙⩙

Notes:

When only ◎ is shown, the maximum single knot is in the maximum group.

The upper break symbol shows location of break for pole tops only.

Point of load for all pole tests was approximately two feet from top, and generally one foot or less for all pole top tests.

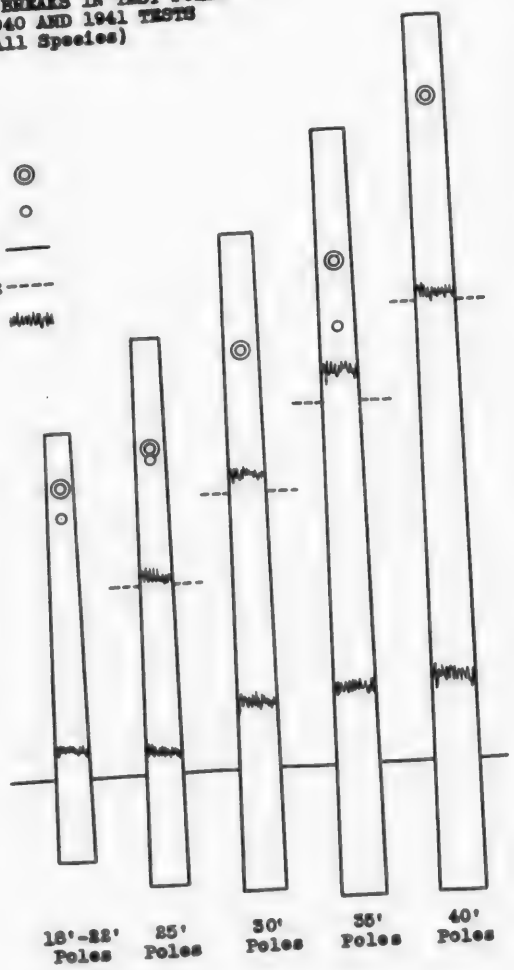


Fig. 9--Diagram showing average location of knots and breaks in the 1939, 1940 and 1941 test poles.

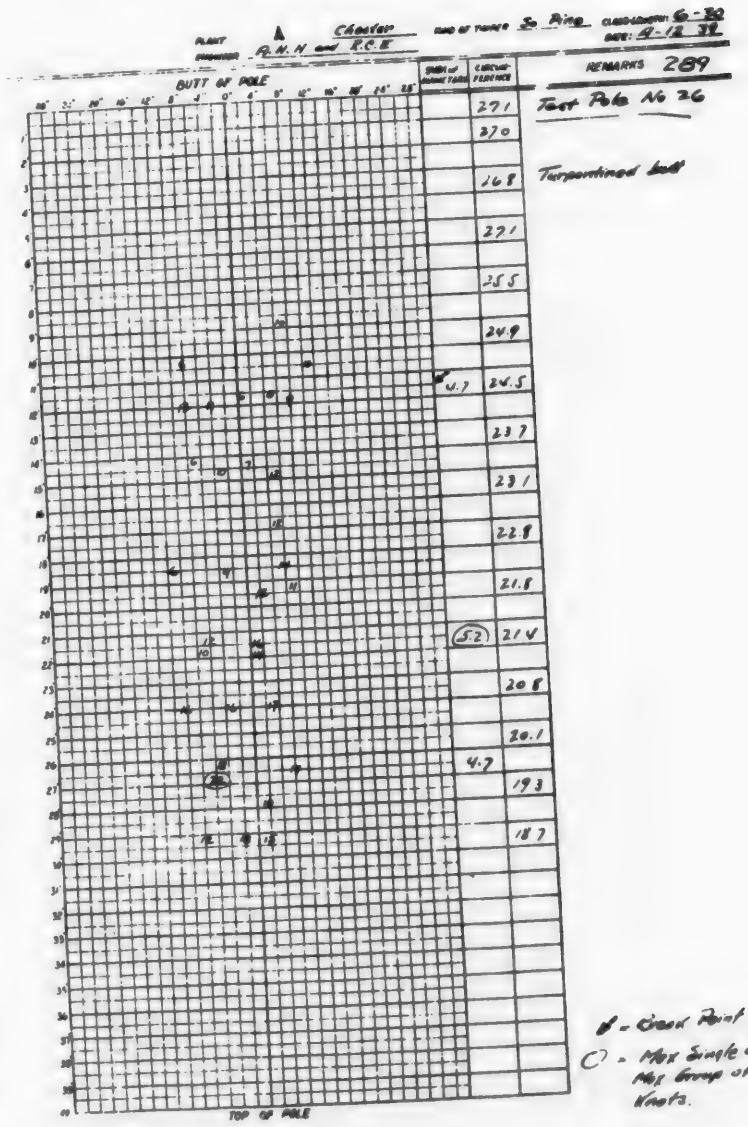


Fig. 10--Knot data sheet.

Salt Treated Poles

Of the 250 salt treated poles tested (viz. 226 southern pine greensalt and Celcure poles; and 24 lodgepole pine, Douglas-fir and western cedar greensalt poles) 143 were southern pine poles treated at Plant A under the direction of G. Q. Lumsden in August and September, 1938, following eight to nine months seasoning for the seasoned group of 111 poles and about one week's seasoning for the unseasoned group of 32 poles. None of the seasoned poles were steamed, while all but seven of the unseasoned poles were steamed in the course of treatment. The seven unseasoned unsteamed poles received the so-called "Flutter" treatment in which the pressure was applied and released thrice during the impregnation period. The 143 poles were selected at random from a lot included in the first large-scale experimental greensalt treatments carried out on full-sized poles.[8] These poles were shipped late in November, 1938. Upon arrival at Chester on December 2, 1938, they were laid side by side on skids. On May 18 and 19, 1939, 13 of the steamed and 36 of the unsteamed poles were placed in the butt-soaking shed where they remained until tested. On June 14, 1950, 5 of the steamed and 19 of the unsteamed poles were set in the ground and on June 26, 1940 the remaining 70 poles (14 steamed and 56 unsteamed) were placed upright in a drying rack, in which locations they remained until tested.

In addition to the 143 poles just described, 107 poles of mixed species were selected from a commercial lot of greensalt poles treated in 1940 at Plant A. The treatment of these poles is described in the same paper cited in connection with the 143 Plant A poles of 1938 vintage. All of the 107 were air seasoned prior to treatment. The southern pine poles were seasoned from two to eight months, depending upon size, to a weight of less than 42.5 pounds per cubic foot. The lodgepole pine and cedar poles were air seasoned in the West for at least one year. No data are available on the duration of the seasoning period for the Douglas fir poles. The treatments were made between May 27 and July 24, 1940. None of the poles were steamed. On August 14, 1940, they were delivered at Chester, where they lay side by side on skids until about September 1, when 21 were placed upright in a pole drying rack where they remained until tested. Of the 86 left on the skids, 54 were broken in the tests made during the period from September 16 to October 17, 1940. The remaining 32 poles were left on the skids until June 10, 1941, when they were placed upright in the drying racks, where they remained until broken in the tests made in the fall of that year.

[8] Lumsden, G. O. and Hearn, A. H., Greensalt Treatment of Poles Proceedings of American Wood Preservers' Association, 1942, p. 349.

Penta-Petroleum Poles

The 13 D1941 poles were part of a lot of 25 that were treated at Plant D in 1941. No Laboratories representative was present to witness the treatment. The poles arrived on October 7, 1941 at Chester where all but three that were tested lay on skids until April 17, 1942, when 11 were placed in one of the pole drying racks and the rest left on the skids. Ten of these poles (4 from the rack and 6 from the skids) were tested on June 8, 1942.

Fifty-Fifty Penta-Petroleum-Creosote Poles

The 30 E1942 poles were treated at Plant E in July and August, 1942, under the direction of R. H. Colley. Fifteen were given penta-petroleum creosote treatment after steaming for 12-3/4 hours. The remaining 15 (matched mates) were steamed 9 hours and given a straight creosote treatment. The 30 poles arrived atChester about the first of October, 1942, where they lay on skids until October 15, 1942, when ten of them were tested. The rest were then set in the ground where they remained until October 28, 1946, when they were tested. (Table for Appendix 1 on next page).

APPENDIX 2

KNOT AND CIRCUMFERENCE MEASUREMENTS

The technique used in making the knot and circumference measurements was as follows:

1. The poles to be measured were laid out on skids.

2. Before measuring, the pole was rolled so that its face (i.e. its gain side) was up.

3. The zero end of a steel tape was tacked to the butt surface of the pole in such a manner that the zero mark coincided with the uppermost point of the butt surface.

4. The tape was then stretched tightly along the longitudinal center line of the face of the pole and by use of a clamp tacked to the top surface of the pole.

5. At the midpoint between the butt and the top, the tape was stapled to the pole to prevent sag when the pole was subsequently rolled for knot measurement.

6. At intervals of two feet, beginning at the extreme butt, circumferences were measured by one man and recorded by another. (In measuring poles of odd length, the interval between the last two circumference measurements was one foot instead of two feet.) The pole was then rolled through an arc of 90 degrees.

7. Using the tape as a reference line, the measurer now called out for each knot: its distance from the butt of the pole; its distance from the reference line; and its diameter in tenth inches. Suppose, for example, that a knot 1.4 inches in diameter were observed at 18 feet 3 inches from the butt of the pole and at a circumferential distance of seven inches from the tape, and that the note recorder were standing at the top of the pole, which has been so rotated that the tape is on the right side of the pole. For the observed knot the measurer would call out, "Eighteen-three, seven over, fourteen," and the recorder would put the figure 14 in the middle of the space between the 18-foot and the 18-1/2-foot mark from the butt and between the 6-inch and 8-inch mark to the left of the heavy center line on the knot data sheet shown in Fig. 10. (This heavy line on the data sheet represents the longitudinal center line of the face of the pole - i.e. the tape).

8. As each knot was measured a keel mark was made on it so that its measurement would not be repeated. After measuring and recording all the knots that could be reached conveniently with the pole in this position, the pole was rolled 180 degrees, so that the balance of the knots could be measured and recorded on the opposite side of the heavy line of the data sheet.

9. A record of any probable strength reducing defects other than knots observed during the measuring process was also recorded under "Remarks" on the data sheet.

Summary of Pole History — From Date of Arrival at Chester to Date of Test

No. of Poles	Pole Group	On Skids (Weeks)	In Rack (Weeks)	In Shed (Weeks)	In Ground (Weeks)	Date Tested
Untreated Poles:						
10	A1938	30				
9	B1938	26				
1	B1938	29				
20				3		1939
Creosoted Poles:						
6	A1937	78				1939
20	B1938	20		16		1939
11	B1938	30			60	1940
9	B1938	30			114	1941
8	B1938	78	13			1940
8	B1938	78	66			1941
5	C1940	2			12	1940
10	C1940	2			64	1941
5	C1940	2	11			1940
82						
Greensalt and Celcure Poles:						
49	A1938	24		16		1939
24	A1938	83			14	1940
25	A1938	84	13			1940
45	A1938	84	65			1941
54	A1940	7				1940
21	A1940	3	56			1941
32	A1940	43	16			1941
250						
Penta-Petroleum Poles:						
3	D1941	Tested on day of arrival				1941
6	D1941	36				1942
4	D1941	27	9			1942
Penta-Petroleum-Creosote and Straight Creosote Poles:						
10	E1942	2				1942
20	E1942	59			153	1946
43						

APPENDIX 3

SPEED OF LOAD APPLICATION

The speed of load application for these tests was determined from the following formula suggested by the U. S. Forest Products Laboratory.

$$N = \frac{2\pi Z L^2}{3C_t}$$

in which

N = Rate of deflection in inches per minute;

Z = Rate of fibre strain in inches per inch per minute = 0.0007, which is the value specified in the A.S.T.M. "Standard Methods for Conducting Static Tests of Timbers in Structural Sizes;"

L = Lever Arm in inches; and

C_t = Circumference at point of load in inches.

For example, the rate of deflection for a 30 foot pole with a circumference at point of load of 19.5 inches would be

$$N = \frac{2\pi 0.0000\ (270)^2}{3(19.5)} = \frac{320.6317}{58.5}$$

N = 5.5 inches per minute

APPENDIX 4

WINCH POSITION

An ideal design of field testing apparatus would be one in which the direction of the pull would at all times be perpendicular to the axis of the pole in its initial position in the testing crib. It is especially desirable that such perpendicularity obtain at the time of break, in order to eliminate the necessity for the correction of the maximum loads for angularity of pull. A design of the ideal sort, however, would be complicated and impractical.

As a practical compromise with the ideal setup, it was decided to set the winch (1) far enough away from the pole to make the angle between the initial and final positions of the pulling line small, and (2) also slightly towards the pole butt, as further insurance that the pulling line in its final position would be perpendicular to the axis of the pole in its initial position.

Accordingly, the stakes that were set in the field to mark the winch positions were located as follows:

(1) At a distance from the face of the testing crib (ground line position) measured parallel to the pole axis, equal to the nominal pole length, minus two feet, minus nominal setting depth, minus a distance equal to approximately two per cent[9] of the poles nominal length; and

(2) At a distance perpendicular to the axis of the pole, in its initial position in the crib, equal to five times[10] the nominal pole length.

The winch positions for the different lengths of pole tested were as follows:

Pole Length Feet	(1) Distance from crib face Feet - inches	(2) Distance from pole axis Feet
18	12 - 2	90
20	13 - 7	100
22	15 - 7	110
25	17 - 6	125
30	21 - 11	150
35	26 - 4	175
40	31 - 2	200

APPENDIX 5

CORRECTION OF "S" READINGS

As stated in the report, the tape from which the "t" readings[11] were read was kept as nearly perpendicular as possible to the datum rail. While the effect of deviations from perpendicularity was negligible on the "t" readings, the effect on the "s" readings[12] was considerable.

In order to check and correct the "s" readings the following procedure was carried out for each pole tested:

(1) A load-deflection curve of the last four "t" readings and corresponding loads was plotted.

(2) From this curve the "t" readings for the breaking load was extrapolated.

(3) A second curve was then plotted of the last four "s" readings based on the deflections read from the load-deflection curve.

Note: As an aid in plotting this curve, the minimum possible "s" values associated with the given deflections were also plotted. These minimum "s" values were computed by the following formula:

---

[9] Based on available pole deflection data it was estimated that the movement of the load point of a pole under test toward the butt would on the average approximate two percent of the pole length.

[10] By field trial a winch position five pole lengths distant proved satisfactory for convenient operation of the blocks and tackle employed; and this distance was also considered sufficiently great to result in a negligible angle between the initial and final directions of pull.

[11] Deflection measured at load point.

[12] Movement of load point toward pole butt.

$S = L - \sqrt{L^2 - t^2}$

in which

S = Minimum "s" for a given deflection,

L = Length of pole from point of load to ground line, and

t = Deflection.

(4) From this second curve was read the final "s" value (viz. the "s" reading correlated with the "t" reading at break).

The curves and computations referred to in this appendix have been filed with the test data sheets.

Appendix 5

Data Sheet 1

Pole Strength Tests

Test Pole No. 26

Species: So. Pine Class and Length: 6 – 30 Weight (Lbs.):

Plant and Treatment: A Split

CIRCUMFERENCES (Inches)

GL*: 26.9 Load Point: 19.1 Top: 18.5

LENGTHS (Ft. - Ins.)

Butt to GL*: 5' - 5 3/4" GL* to Load Point: 22' - 6" Load Point to Break: 16' - 6 1/2"

Obs. Dyn. 'Pounds	t* (Ft. - Ins.)		s* (Ins.)	g* (Ins.)	Remarks
0	10	8 3/4	5	0	
200	11	1/2	5 7/8	0	
400	11	3 7/8	6 1/4	1/16 -	
600	11	9 1/4	6 1/4	1/16 -	
800	12	1	6 3/8	1/8	
1000	12	6	6 5/8	3/16 -	Start time
1200	12	10 3/8	6 7/8	3/16	
1400	13	4 1/8	7 1/8	1/4	
1600	13	11 1/2	7 3/8	5/16	3 m. 45 s.
1800	14	8 7/8	7 1/2	3/8	
2000	(14.95=Est.)		(8 = Est.)		1840 max.
2200			10.0		Short break at knot whorl.
2400			(9.8min)		
2600					
2800					
3000					
3200					
3400					
3600					
3800					
4000					Total 5 = 5"

* GL (Ground Line) = Point of Support.
t = Perpendicular distance from top datum to load point.
s = Distance load point moves toward butt.
g = Distance pole moves at ground line.

Initials of Recorder and Date: RCL 4-5-39

Pole Strength Tests — Data Sheet 2 — Appendix 5 — Test Pole No. 26

Dynamometer Observed (Pounds)	Dynamometer Corrected* (Pounds)	Corrected** Deflection (Inches)	Sec.	Circumference (Inches)
0			Butt	27.1
200	190		2'	27.0
400	350		4'	26.8
600	550		6'	27.1
800	750		8'	25.5
1000	980		10'	24.9
1200	1170		12'	24.5
1400	1370		14'	23.7
1600	1560		16'	23.1
1800	1790		18'	22.8
2000			20'	21.8
2200			22'	21.4
2400			24'	20.8
2600			26'	20.1
2800			28'	19.3
3000			30'	18.7
3200			GL	26.9
3400			11'5¼" Break	24.6
3600				
3800				
4000				

$$MR = \frac{K\,L\,W}{C_g^3} \quad \text{and} \quad MB = \frac{K\,L'W}{C_b^3}$$

where:

K = $32\,\pi^2$ = 315.82734

L and L' = Lever arms, in inches

W = Maximum load, in pounds

C_g and C_b = Circumferences at ground line and at break, respectively, in inches.

Distance	Inches
Load Point to GL*	270
Total s*	5
	265
L =	
Load Point to Break	199
Total s*	5
L' =	194

W = 1835 pounds

C_g^3 = 19465.109

C_b^3 = 14886.936

Modulus of Rupture (MR): 7890 lbs./sq.in.

Max. Fiber Stress at Break Section (MB): 7550 lbs./sq.in.

* Corrections based on calibration curves.

**Corrected deflection = Difference between the t values of Data Sheet 1 for any load and zero load, minus a correction for movement at point of support.

* See Data Sheet 1.

Initials and Date: REG 4-16-40

Pole Strength Tests — Data Sheet 3 — Appendix 5 — Test Pole No.

MOISTURE CONTENT AND SPECIFIC GRAVITY

Location in Disc	15'1" Disc above Break: Moist. Per Cent	Sp. Gravity Vol. Dry	Sp. Gravity Vol. Wet	Preservative, Lbs. per Cu. ft.	Disc 1' below GL: Moist. Per Cent	Sp. Gravity Vol. Dry	Sp. Gravity Vol. Wet	Preservative, Lbs. per Cu. Ft.
Outer 1/4"	15.3	0.594	0.517		85.8	0.608	0.528	
Next 1/4"	17.4	.565	.495		59.8	.630	.541	
" 1/2"	17.6	.563	.493		42.2	.616	.532	
" 1/2"	19.4	.539	.473		33.6	.570	.496	
" 1/2"								
" 1/2"								
Sap.) T	21.0	.539	.475		43.3	.605	.525	
Sap.) U	18.2	.558	.490		52.3	.604	.525	
Heart	17.4	.612	.531		24.9	.798	.665	
Overall	18.1	.547	.496		44.0	.643	.554	
Entire Disc*								

RATE OF GROWTH AND PER CENT OF SUMMER WOOD

	Upper Disc	Lower Disc
Average Radius (Inches)	3.68	4.23
Total No. of Rings		
Rings per Inch		
Total Summer Wood Width (Inches)		
Total Radius (Inches) (In Depth Sapwood)	2.16	2.34
Per Cent of Summer Wood		

*Measurements not required in case of creosoted poles.

Initials and Date: Chem. Lab NOV 1939

Some Characteristics of Young Plantation-Grown Red Pine in Relation to Properties of the Wood

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SUMMARY

YOUNG RED PINES grown in plantations were found to have wood of lower average specific gravity than older trees from natural stands, but specific gravity increased with percent of summerwood that, in turn, increased from the pith outward. In the young trees, longitudinal shrinkage frequently was much larger, particularly in wood near the pith with small percents of summerwood, than the usual range of 0.1 to 0.3 percent of the green length. Specific gravity and longitudinal shrinkage of wood were found to be jointly related to compressive strength along the grain, so that from basic information on such physical properties better estimates of strength properties can be obtained than from use either of specific gravity or of longitudinal shrinkage alone as an index of strength.

Mutual relationships of specific gravity and longitudinal shrinkage to strength in compression along the grain were determined in plantation-grown red pine (Pinus resinosa). In addition, patterns of growth, percentages of summerwood, and specific gravity of the wood in young trees were determined as part of this work.

Specific gravity alone is a general index of endwise compressive strength; however, some pieces of wood are known to have greater strength than others, when all have about the same specific gravity. It also was discovered that both excessive shrinkage and poor compressive strength along the grain were associated with a common factor of the anatomy of the wood, namely, orientation of fibrils making up the cell wall at large angles to the length of fibers.[2] Thus, intrinsic characteristics of wood are related to its properties that, in turn, affect the behavior of lumber in service.

Red pine is a commonly used species for forest and wood-lot plantations in the Lake States region and Northeastern States, but wood of several young plantation trees was found to be relatively light in weight for that species. That characteristic pointed to a need for information on variations in qualities of wood in plantation-grown trees, and also on interrelationships among properties of that wood. Such information is useful to determine whether silvicultural measures are necessary to improve the qualities of the wood, and also to determine basic relationships of strength to certain physical properties of the wood as evaluated from simple determinations. The work included coordinate phases of evaluation of intrinsic characteristics of wood in young red pine grown in plantations, namely:

1. Patterns of variations in diameter increment, percentages of summerwood, its relation to specific gravity, and the variations in longitudinal shrinkage.[3]

2. Basic relationships between density, longitudinal shrinkage, and compressive strength along the grain.

PLAN OF WORK AND SOURCES OF MATERIAL

The phase of the work for determining variations in diameter increment, percentages of summerwood, and general physical properties of the wood was done on trees from 11 plantations, 14 to 37 years old from seed, in the Lake States region. The determinations were made on 54 sample trees representing dominant, codominant, and intermediate classes, whereever these were present in the plantations. Site indexes of the different plantations were estimated as 40 feet or 60 feet at a projected age of 50 years. Those estimates were based on ages and heights of dominant and codominant sample trees from each plantation.

Sampling within the trees included successive periods of growth, of 5 to 15 years each, in the cross sections and at different heights about the ground. Thereby thorough representation was obtained for the young red pines. Determinations of number of annual rings per radial inch and their percentages of summerwood were made on green wood; specific gravity was based

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] M. Y. Pillow, and R. F. Luxford. Structure, Occurrence, and Properties of Compression Wood. U. S. Dept. of Agric. Tech. Bul. 546. January 1937.

[3] This phase of the work was done largely by Dr. Eric A. Anderson, New York State College of Forestry, Syracuse University; formerly Forest Products Technologist, Forest Products Laboratory, Madison, Wis.

on green volume and oven-dry weight; and longitudinal shrinkage was based on the percent of change from the green length.

The other phase of the work on relationships of compressive strength along the grain to specific gravity and longitudinal shrinkage was done on a comparatively small number of specimens selected from those used to determine variability in longitudinal shrinkage in all sample trees. Thirty-one specimens were chosen that represented about the same range in longitudinal shrinkage as the larger number of original specimens. Since the 31 specimens were selected solely on a basis of shrinkage along the grain, their other characteristics were strictly at random.

Because the specimens originally has been oven-dried to determine total shrinkage along the grain, those selected were soaked in distilled water to return them approximately to their green dimensions. Thereafter, two specimens, 5/8 inch square in cross sections and 2-1/2 inches along the grain, were cut from each of the selected specimens to determine the specific gravity and end-crushing strength of each, for correlation of these values with the longitudinal shrinkage that originally had been determined for the entire specimen. An additional section, closely matched with the strength-test specimen, also was obtained for measurement of widths of complete annual rings and their percents of summerwood (Fig. 1).

CHARACTERISTICS OF GROWTH, DENSITY, AND SHRINKAGE

A general pattern of relatively wide annual rings near the pith, with successively narrower rings towards the bark, was found in the plantation-grown red pine. Such a pattern may occur also in naturally seeded trees originating with wide spacing in open areas. The environmental factor of spacing of young trees was found by Paul[4] to have a marked effect on diameter increment. In comparable positions in the plantation red pine, percentages of summerwood increased in successive 5-year periods from the pith to the bark (Fig. 2).

Average specific gravity for wood from all positions in the 54 trees was 0.351, based on green volume and oven-dry weight. Wood from the young, plantation-grown trees averaged less in specific gravity than that of 70-year-old and of 25-year old[5] naturally seeded trees, having respective values of 0.390 and 0.440. These data on average specific gravity of red pines indicated that heavier wood was formed as the trees became older.

The over-all data for the plantation-grown red pine indicated relationships of increasing specific gravity with percentages of summerwood that, in turn, increased with numbers of annual rings. That trend was confirmed by the data from the selected specimens on which percentages of summerwood and specific gravity were determined on the same specimens. Table 1 shows data on percentages of summerwood and specific gravity of the selected specimens. Specific gravity was significantly correlated with percentages of summerwood (correlation coefficient, $r = 0.661$ at 29 degrees of freedom), and the relation was linear, as is shown in Figure 3.

Some of the plotted points of that relation, however, deviated considerably from the regression line and thereby indicated that other factors than percentages of summerwood contributed to variations in specific gravity. The equation for regression of specific gravity on percent of summerwood ($Y = 0.290 + 0.003018X$) indicated that specific gravity of springwood alone, that is, wood with 0.0 percent summerwood, was 0.290 on the average in this red pine material. It is known, however, that specific gravity tends to be variable in both springwood and summerwood alone.[6] Thus it appears reasonable that variations in specific gravity of either or both springwood and summerwood can contribute to variations in over-all specific gravity of the wood somewhat independently of proportional amounts of springwood and summerwood.

Average volumetric, radial, and tangential shrinkages of the wood of plantation-grown red pines were somewhat smaller than those of wood of naturally seeded but older trees (Table 2). Relatively small shrinkage of plantation trees also having low specific gravity were in conformity with other data showing that volumetric and transverse shrinkages each tend to be correlated with specific gravity.[7]

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[4] Benson H. Paul. The Application of Silviculture in Controlling Specific Gravity of Wood. U. S. Dept. of Agric. Tech. Bull. 168. January 1930.

[5] L. J. Markwardt and T. R. C. Wilson. Strength and Related Properties of Wood Grown in the United States. U. S. Dept. of Agric Tech. Bull. 479. September 1935.

[6] Benson H. Paul. Variations in the Specific Gravity of Springwood and Summerwood of Four Species of Southern Pines. Journ. of Forestry XXXVII (6), June 1939.

[7] J. A. Newlin and T. R. C. Wilson. The Relation of the Shrinkage and Strength Properties of Wood to Its Specific Gravity. U. S. Dept. of Agric. Bul. No. 676. July 16, 1919.

Longitudinal shrinkage from green to oven-dry condition of wood representing all the plantation-grown trees showed a wide range of variation in values, that is, from 0.093 to 1.411 percent of the green length of the specimens. The average shrinkage along the grain was 0.304 percent. Specimens with the largest shrinkage values originated principally within 2-1/2 inches of the pith in the lower part of the trees, and within 1-1/2 inches from the pith at high levels.

The longitudinal shrinkage of the selected specimens, which had about the same range as all specimens from the 54 plantation trees, was correlated with average width of the complete annual rings (4 = 0.759 at 29 degrees of freedom). Some specimens with wide annual rings formed early in the life of the trees and others with compression wood, which has intrinsically large shrinkage along the grain,[2] were included in the selected specimens. Figure 4 shows the relation of increasing longitudinal shrinkage with increase in width of annual rings, and the relation appeared to be satisfactorily expressed by a free-hand curve. Table 1 shows data on width of annual rings and longitudinal shrinkage of those specimens.

On the other hand, longitudinal shrinkage for all the selected specimens showed essentially no correlation with specific gravity (Fig. 5). The nominal range of longitudinal shrinkage is considered to be between 0.1 and 0.3 percent of the green length of the test specimens.[8] Of selected red pine specimens having shrinkage less than 0.3 percent, the longitudinal shrinkage tended to decrease as specific gravity increased, as is indicated by the straight-line regression among these data (Fig. 5). However, specimens with more than 0.3 percent shrinkage showed no relation to specific gravity. The data on longitudinal shrinkage of the selected specimens of red pine represented two categories: (1) nominal shrinkage of less than 0.3 percent, and (2) excessive shrinkage of more than 0.3 percent along the grain. Thus, nominal shrinkage along the grain was inversely related to specific gravity, but excessive shrinkage was associated with some undetermined characteristics of comparatively wide annual rings formed early in the trees and of rings containing compression wood.

[8] Arthur Koehler. Longitudinal Shrinkage of Wood. For. Prod. Lab. Report No. R1093, Rev. September 1946.

RELATIONS OF COMPRESSIVE STRENGTH TO SPECIFIC GRAVITY AND LONGITUDINAL SHRINKAGE

Data on specific gravity and maximum crushing strength along the grain are shown in Table 1, arranged in order of increasing longitudinal shrinkage of the original 31 specimens from which the smaller test specimens were obtained (Fig. 1). Average values, standard deviations, and coefficient of variation (st. dev./av . x 100) show comparative variability in each of the characteristics that were measured for the selected specimens.

Relation of Strength and Specific Gravity

Maximum crushing strength along the grain of plantation-grown red pine was found to increase with specific gravity in conformity with the general relationship between those properties,[7] and as a straight-line relationship (Fig. 6). The data, however, showed considerable variation in resistance to crushing along the grain in specimens with nearly the same specific gravity, and thereby indicated that other factors than specific gravity also affected the strength. It was observed that specimens with relatively small shrinkage along the grain also tended to have larger values in crushing strength than other specimens with relatively large shrinkage (Table 1).

Relation of Strength and Longitudinal Shrinkage

Longitudinal shrinkage was found to have highly significant correlation with maximum crushing strength along the grain of red pine when logarithmic values for these properties were used in calculation of the correlation coefficient, r = 0.774 at 29 degrees of freedom. Desirability for transformation of actual values to their Logarithms was indicated by the obviously curved pattern of plotted data for strength in relation to longitudinal shrinkage (Fig. 7).

It is not reasonable, however, to conclude that the endwise compressive resistance of the wood depends on longitudinal shrinkage of the wood; but, rather, it is reasonable hypothesis that both the compressive strength and longitudinal shrinkage was affected by some other characteristics of the wood. For example, large fibril angles in the cell wall with respect to the length of fibers is an important cause of large shrinkage along the grain in many species.[8] Other work at the Forest Products Laboratory has shown that fibril angles affect certain strength properties, not only in abnormal compression wood,[2] but also in white ash in which strength was inversely correlated with fibril angle more or less irrespective of specific

gravity. Because of such effects of basic anatomy of the wood on its properties, longitudinal shrinkage, in addition to specific gravity, appeared to be an index of crushing strength along the grain in plantation-grown red pine.

Joint Relations of Gravity, Shrinkage, and Strength

Relations between one variable and two others operating jointly can be shown in a three-dimensional graph. Such jointly operating relations[9] were determined from alternate approximations of strength values to longitudinal shrinkage and to specific gravity until estimated values for strength closely followed approximation lines. Nine approximations were necessary to obtain reasonably stable lines when replotted from the successively determined approximations that represented average relations in respective classes of specific gravity and longitudinal shrinkage. The first approximations, however, were calculated as regressions of compressive strength with longitudinal shrinkage in different classifications of specific gravity.

Values estimated from the final approximations of maximum crushing strength along the grain showed the trends of changes in strength in relation to jointly occurring changes in both specific gravity and longitudinal shrinkage in the test specimens. These data showed (1) that the maximum crushing strength decreased as longitudinal shrinkage increased in each classification of specific gravity, and (2) that strength increased as specific gravity increased in each classification of longitudinal shrinkage. Both these relationships tended to be slightly curved and, when they were assembled in a three-dimensional graph, the shape of the upper surface showed the trends of variations in compressive strength along the grain with jointly functioning variations in both specific gravity and longitudinal shrinkage of the wood (Fig. 8). The estimated values of the crushing strength in comparison with the actual values for the tests in each two-way classification by specific gravity and longitudinal shrinkage are shown in Table 3.

Although specific gravity and longitudinal shrinkage are separate indexes of endwise compressive strength of red pine, greater accuracy for estimations of its strength can be obtained by use of joint functions of two physical properties in relation to a strength property. The practical significance of such basic information lies in the possibilities of estimating certain strength properties from relatively simple determinations of specific gravity and longitudinal shrinkage of a piece of wood when such joint functions are known for the particular kind of wood.

[9] Mordecai Ezekiel. Methods of Correlation Analysis. New York, 1947.

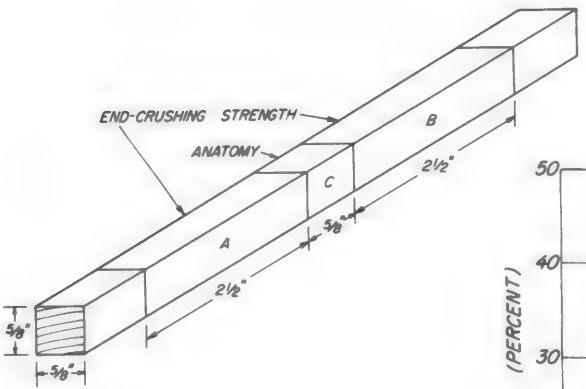
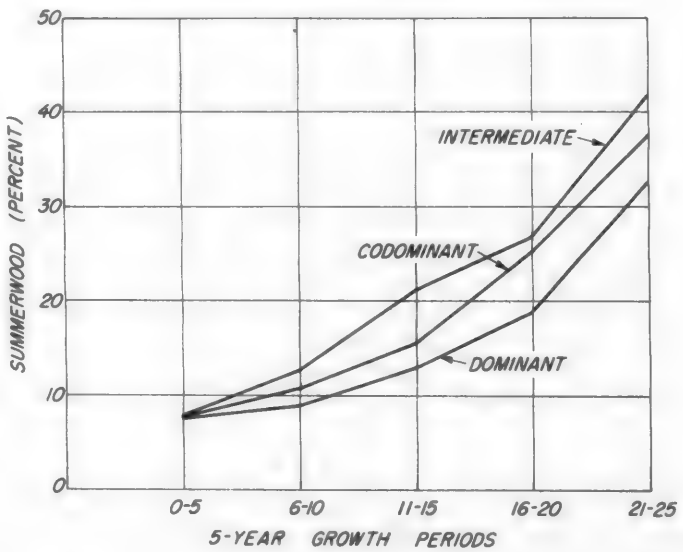


Fig. 1—Relative positions of specimens A and B for determinations of end-crushing strength, and of specimen C for measurement of width of annual rings and their percent of summerwood in selected stocks previously used for determination of longitudinal shrinkage of plantation-grown red pine.

Fig. 2—Average of percentages of summerwood in 5-year periods for dominant, codominant, and intermediate red pines grown in plantations.



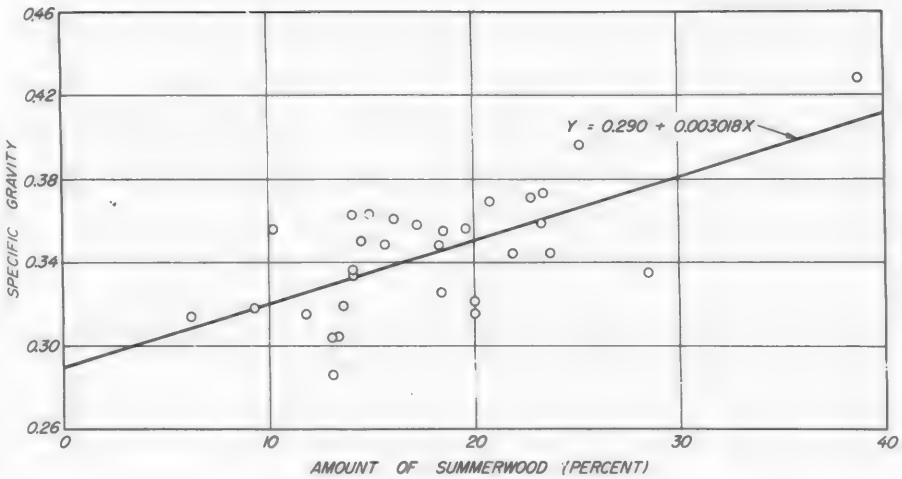


Fig. 3--Relation of specific gravity to percentage of summerwood of selected specimens of plantation-grown red pine.

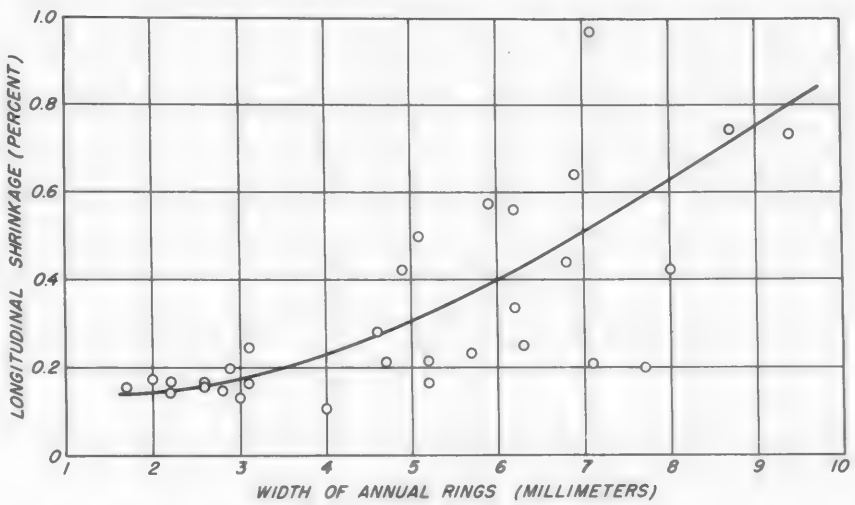


Fig. 4--Relation of longitudinal shrinkage to width of annual rings of selected specimens of plantation-grown red pine.

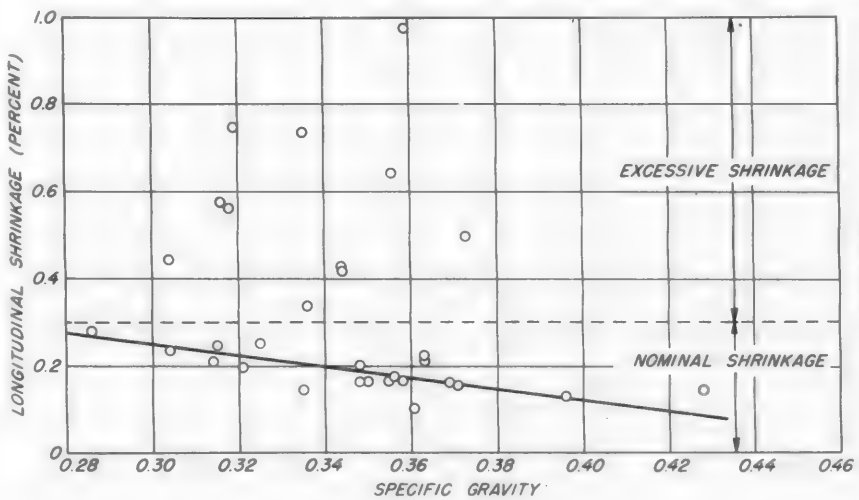
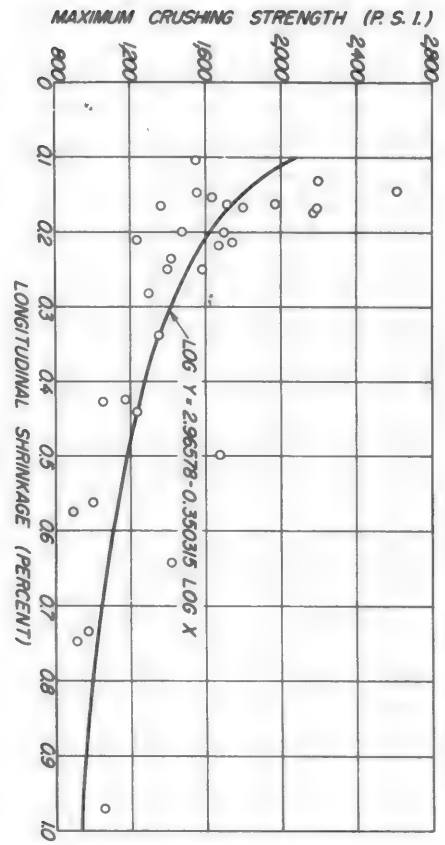
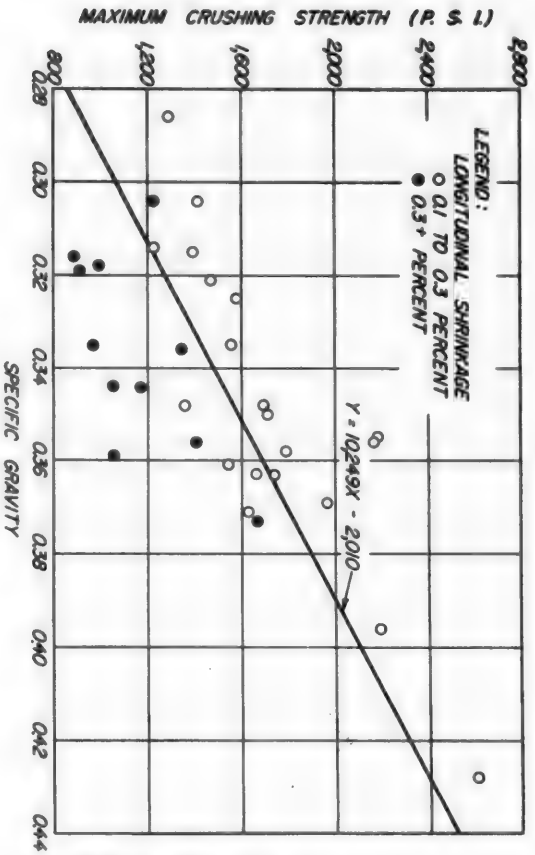


Fig. 5--Relation of nominal and excessive longitudinal shrinkage to specific gravity in selected specimens of plantation-grown red pine.





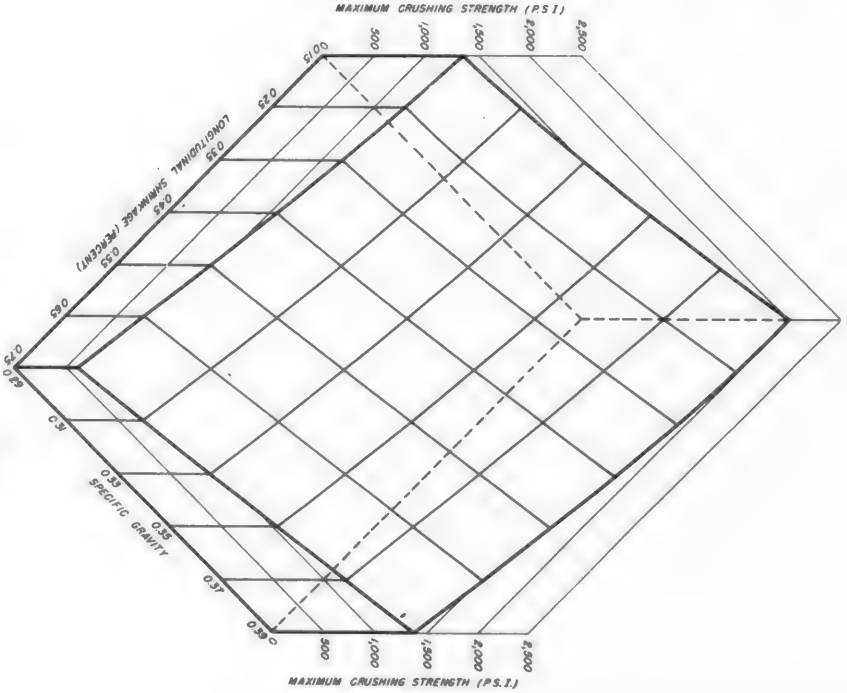


Fig. 6--Relation of maximum crushing strength along the grain to specific gravity of selected specimens of plantation-grown red pine.

Fig. 7--Relation of maximum crushing strngth along the grain to longitudinal shrinkage of selected specimens of plantation-grown red pine.

Fig. 8--Interrelationship of maximum crushing strength along the grain to longitudinal shrinkage and specific gravity of selected specimens of plantation-grown red pine.

Table 1.--Width of annual ring, percents of summerwood, specific gravity, and maximum crushing strength along the grain arranged in order of longitudinal shrinkage for selected specimens of red pine grown in plantations

Serial No.	Longitudinal shrinkage	Width of annual rings	Amount of summerwood	Specific gravity	Maximum crushing strength
	Percent	Mm.	Mm.		P.s.i.
19	0.104	4.0	16.1	0.361	1,542
14	.131	3.0	25.2	.392	2,197
20	.145	2.2	38.7	.428	2,614
18	.148	2.8	14.1	.335	1,557
28	.154	1.7	22.8	.371	1,635
15	.162	2.6	14.5	.350	1,764
22	.162	3.1	20.8	.369	1,966
13	.165	5.2	18.3	.348	1,360
26	.167	2.6	17.2	.358	1,793
16	.168	2.2	18.5	.355	2,186
23	.174	2.0	19.6	.356	2,177
9	.199	7.7	20.0	.321	1,472
12	.200	2.9	15.7	.348	1,699
1	.210	7.1	6.2	.314	1,235
21	.212	4.7	14.9	.363	1,740
25	.218	5.2	14.1	.363	1,666
10	.235	5.7	13.3	.304	1,413
11	.249	3.1	11.8	.315	1,394
4	.250	6.3	18.4	.325	1,580
7	.281	4.6	13.1	.286	1,296
17	.338	6.2	14.1	.336	1,352
31	.426	8.0	23.7	.344	1,170
2	.428	4.9	21.9	.344	1,054
3	.441	6.8	13.1	.304	1,236
29	.498	5.1	23.4	.373	1,670
30	.563	6.2	9.3	.318	996
6	.576	5.9	20.0	.316	889
24	.643	6.9	10.2	.356	1,412
8	.734	9.4	28.5	.335	972
5	.747	8.9	13.6	.319	911
27	.971	7.1	23.3	.359	1,056
Average	.326	5.0	17.9	.344	1,515
Standard deviation	.2212	2.16	6.42	.0291	416
Coefficient of variation (percent)	67.9	44.1	35.9	8.5	27.5

Table 2.--Average specific gravity and volumetric, radial, and tangential shrinkage of young plantation-grown red pine in comparison with older forest-grown trees

Source	Age	Specific gravity[1]	Total shrinkage[2]		
			Volumetric	Radial	Tangential
	Years		Percent	Percent	Percent
Plantation	14 to 37	0.351	9.9	3.1	6.4
Forest	70	.390	11.2	3.4	7.2
Forest	250	.440	11.5	4.6	7.2

[1] Based on green volume and oven-dry weight.

[2] Based on green size.

Table 3.--Estimated values for compressive strength along the grain (in parentheses) from approximations by two-way classification of specific gravity and longitudinal shrinkage in comparison with the actual test values of plantation-grown red pine

Classes of specific gravity	Classes of longitudinal shrinkage (percent)						
	0.10-0.19	0.20-0.29	0.30-0.39	0.40-0.49	0.50-0.59	0.60-0.69	0.70+
	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.	P.s.i.
0.280-0.299	(1,360)	(1,290)	(1,180)	(1,050)	(900)	(750)	(590)
	(1)	1,296	(1)	(1)	(1)	(1)	(1)
.300-.319	(1,420)	(1,370)	(1,280)	(1,180)	(1,050)	(910)	(740)
	(1)	[2]1,347	(1)	1,236	[2]942	(1)	911
.320-.339	(1,540)	(1,480)	(1,410)	(1,310)	(1,200)	(1,060)	(900)
	[2]1,514	1,580	1,352	(1)	(1)	(1)	972
.340-.359	(1,680)	(1,630)	(1,550)	(1,470)	(1,350)	(1,220)	(1,050)
	[2]1,856	1,699	(1)	[2]1,114	(1)	1,412	1,056
.360-.379	(1,860)	(1,800)	(1,730)	(1,630)	(1,510)	(1,370)	(1,210)
	[2]1,714	[2]1,703	(1)	1,670	(1)	(1)	(1)
.380-.399	(2,060)	(2,000)	(1,930)	(1,830)	(1,700)	(1,540)	(1,370)
	2,197	(1)	(1)	(1)	(1)	(1)	(1)
.400+	2,614	(1)	(1)	(1)	(1)	(1)	(1)

[1] Indicates no test data.

[2] Average of two to five specimens within the classification.

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Recent Investigations on the Avoidance of Decay in Exterior Woodwork of Buildings

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ABSTRACT

RECENT INVESTIGATIONS in the Gulf States indicate that extensive decay of siding usually is a result of fungus infections prior to construction. These increase water absorbency and if a decay fungus is present, create hazards of post-construction infections. In addition to the use of fungus-free lumber, certain structural designs reduce the danger of water accumulations in siding. These are: (1) good roof overhang or at least eaves gutters, (2) the placing of trim over the siding ends when using drop siding, (3) designs that prevent runoff from striking siding or splashing up against siding from porches, etc. and (4) the use of breathing papers or no paper directly under siding.

Steps, porches, and similar structures of high decay hazard usually cannot be sufficiently protected by design if made of sapwood but require preservative treatment. Although commercially impregnated wood is best, worthwhile protection results from on-the-job applications of non-swelling paintable preservatives. Brushing, dips, and short period soaks afford only surface protection; thus treatment should follow all cutting. Dips are not effective unless the treated wood is painted or unless a moisture repellent as an ingredient of the preservative is also used. On-the-job treatments should not be used instead of good design; both are needed.

Until recent years, investigations on building decays emphasized the two water conducting fungi. These cause spectacular damage to attacked buildings but they occur infrequently. Recent research stresses decay by the much commoner fungi associated with rain seepage. Although distinctly less spectacular, such decay undoubtedly causes a greater volume loss of wood in buildings.

RAIN SEEPAGE INTO EXTERIOR WOODWORK

Rain seepage problems have increased now that southern pine heartwood and such other durable woods as heart cypress are less generally available. Also certain building design trends have accentuated seepage troubles.

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One of the characteristics of most heartwood is a resistance to the penetration of water. Probably this was an important factor in the durability of southern pine heartwood in exterior woodwork. In our tests we found southern pine sapwood to be 1.2 to 10.0 (av. 2.8) times as absorbent as heartwood from the same boards. Thus pine sapwood, which has no natural resistance to decay, wets more readily with rain seepage and is more frequently at a moisture content sufficiently high to support growth of a decay fungus. This greater absorbency probably has been of most importance in inducing decay in such structures as exterior steps and porch floors where the decay hazard is high. The likelyhood of decay in siding, on the other hand, is much less, and need not decay extensively merely because it is sapwood. Field surveys indicate that one of the prerequisites of extensive siding decay is fungus infection prior to construction. Such infections may be of the decay, stain, or mold type. Most decay fungi are not killed by air seasoning; they can survive dormantly for months or even years, reviving each time favorable moisture conditions prevail. Heavily stained lumber frequently contains incipient decay infections even though these are not visible to the naked eye. Therefore, badly stained lumber is a poor risk for any use where it may get wet, both because it is more absorbent and because of the danger of decay infections. Wood with surface molds, even without stain, is also hazardous because of its increased absorbency. We believe that one of the fundamentals of decay control in exterior woodwork is the use of fungus-free lumber. Lumber cut from fresh logs, treated with a stain-control dip, and properly air-seasoned makes good exterior woodwork. Kiln-dried lumber is probably a little safer than lumber that has been air-seasoned during very moist warm weather. Lumber whether kiln- or air-dried, must be protected from rain and soil moisture during transit and storage prior to use. In other words, dangerous fungus infections can result from mishandling lumber at any time up to its incorporation in the building.

Four design factors seem to have most influence on moisture problems arising from rain seepage into siding and exterior woodwork: (1) roof overhang appears important in decreasing rain seepage into joints of exterior woodwork. Experimental evidence is lacking but observations indicate that overhangs of 8 inches are beneficial and those of 24 inches give almost complete

protection to one-story houses even without rain gutters. (2) All serious siding decay we have found was associated with siding butted to the edge of the trim in the usually approved manner. In such a joint, end grain, which is most penetrable, is exposed to rain seepage. The greater workability of sapwood probably decreases the chance of sealing joints with repeated painting. Conversely, both field observations and experimental data suggest that the placement of trim over drop siding not only creates no decay hazard as previously supposed but actually decreases water seepage. In the case of pine sapwood bevel siding, trim placed over siding ends does not reduce seepage. The problem of the type of joints is lessened when good roof overhang is provided, particularly if rain gutters are used and properly maintained. (3) Rain splash from porch floors or other horizontal surfaces near wooden walls, roof designs that allow concentrated roof runoff to strike siding, or leaks in down spouts can lead to sufficient moisture seepage to induce decay. (4) The rate of drying of rain-wetted siding is chiefly a function of the type of sheathing paper used. Vapor-barrier papers materially impede drying. In our panel tests, moisture readings were taken on 134 days during the first half of 1951. The average percentages of dry siding ends (i.e. less than 20 percent moisture) were about 95 for panels without sheathing paper or with a breathing paper and about 50 for panels over a vapor-barrier paper. Furthermore, in most cases of severe siding decay in the South, we have found vapor-barrier papers under the siding.

In structures of high decay hazard, such as exterior steps, porch floors, and porch and step rails, our tests show a certain amount of protection resulting from designs promoting rain runoff. Thus less decay occurs when a step rail is extended over the top of the newel than when it is butted to the side of the newel. However, when non-durable sapwood is involved, the degree of benefit is not sufficient to warrant depending on design alone to prevent decay. For these structures of high decay hazard, protection will come largely from the use of wood substitutes, naturally decay-resistant wood, or preservative-treated wood.

PRESERVATIVE TREATMENTS FOR EXTERIOR WOODWORK

During recent years we have advocated the use of on-the-job applications of preservatives for wood used off the ground but subject to rain seepage at joints, when lumber treated by pressure or hot and cold bath was not available. We now have data to better define the limits of usefulness of simple surface treatments.

Siding, if protected from rain as noted earlier, is not considered in need of preservative treatment, except perhaps on boards near the ground.

Our Saucier, Mississippi, tests on porch, step and rail members indicate that pine sapwood treated with pentachlorophenol (five percent) or copper naphthenate (0.5 percent metallic copper), will give the following service if surfaces exposed to the weather are protected by a standard exterior oil paint: (1) brush applications or dips of a few seconds, three or four years, (2) three-minute dips, five or more years, (3) soaks of 15 minutes or longer, ten or more years. In colder climates or in buildings designed to reduce decay hazard, longer periods of protection undoubtedly will follow.

Samples immersed for three minutes or less and exposed unpainted, however, developed serious internal decay after three to four years unless a moisture repellent had been added to the treating solution. Presumably the paint or a moisture repellent reduces loss of the preservatives and reduces checking through the treated shell with the consequent exposure of untreated wood. The data are still very encouraging but they point more than ever to the need for precautions in using on-the-job applications of preservatives. Precautions include: (1) the use of immersion periods as long as feasible. Whenever feasible, immersions of at least 10 to 15 minutes should be used. If not practicable to immerse the entire piece, ends should be immersed and sides heavily brushed, (2) if treated wood will not be painted, the incorporation of a moisture repellent in the treating solution is well worth while. Also when paintability and drying time are not important heavier oil carriers as diesel fuel or No. 2 fuel oil will give longer protection, (3) because little penetration occurs with any likely on-the-job immersion period, wood should be cut to size and shape prior to treatment. As an alternative, cut surfaces should be retreated, at least by a brush application, (4) when only short-period soaks are used, buildings should be designed to restrict rain seepage and to promote rapid drying of any wetted wood, (5) clean lumber should be used in order to reduce the chance of internal decay. Should conditions require the use of infected lumber where rain seepage may occur, preservative treatment is particularly needed. For infected lumber, a moisture-repellent preservative should be particularly desirable.

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Uniform Standards Essential to the Advancement of the Hardboard Industry

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THE NEED FOR STANDARDS

WHEN A NUMBER of manufacturers produce similar commodities by a variety of techniques, the need for uniform standards is most urgent if the prospective user is to have confidence in any one or all of the materials concerned. Lumber, plywood, and now hardboard are good examples. Sometimes one firm dominates production and is practically an industry in itself. In other cases many variations, small and large, occur under one common designation such as furniture, automobiles, and appliances. It is doubtful that specifications of the kind we are prepared to discuss would be very effective under either of these conditions. But hardboard is different. It is a structural material. Appearance differences may not turn out to vary too widely either. All hardboards are designed for many of the same uses and will be hitting the same markets. If the market for all hardboards is to be developed successfully, the potential consumer must be told a story which will interest him and inform him--not confuse and exasperate him.

PERFORMANCE - THE COMMON GOAL

This means that we must talk performance. Discussion of the individual materials on anything other than a performance basis will eventually result in complete confusion on the part of the customer and a breakdown in his confidence. For example, here are some differences, any one of which could be built up into quite a story--and a very harmful one, I believe. To begin with manufacturing processes-there is the dry process--the wet process--the semi-dry or damp process--the Masonite process, and I am sure these can be broken down into further variations. There is a question of resin content which might be played up or played down as the need occurred, to say nothing of the type of resin. An issue can be made of the source and type of raw material as well. In any case, it is possible to point with pride or view with alarm, depending on what suits your purpose.

Then there is the descriptive terminology. Standard--tempered--treated--mean different things to different manufacturers, and such terms are used quite loosely. Perhaps these differences can be minimized by cooperative effort, but uniform standards remain a common yardstick regardless of the descriptive designation.

These examples can be carried to a ridiculous extreme, of course, but the danger is very real. A parallel situation in the history of the fir plywood industry can be cited in support of that fact.

When resin-bonded exterior plywood became an industry-wide product, we had a situation where salesmen who knew little or nothing about the formulation of adhesives were warning customers against certain types of resin glues, or, more particularly, other ingredients combined with the resin. References to extenders and fillers were often erroneously made during this period of growing pains.

A performance standard for Exterior-type fir plywood incorporated in the U. S. Commercial Standard for Fir Plywood effectively corrected this situation. The requirements have been a matter of public record and publicized by the Douglas Fir Plywood Association for a number of years now, and exterior plywood can be purchased on the basis of glue line performance required regardless of the various ingredients that go to make up the adhesive in the panel.

STANDARDS - OUR OWN OR SOMEONE ELSE'S

Another very good reason for setting up standards is that, if the industry does not do it, someone else will. Federal Specification LLL-F-311 is the only hardboard standard at the moment. This was written around one manufacturer's product, which is understandable because that producer dominated the field. It is naturally distasteful to new producers, for, in the interest of developing a realistic standard, I think everyone concerned agrees that this specification should be worked over. There is another specification, Commercial Standard CS176-51, which was developed by the manufacturers of prefinished wall panels. It is largely concerned with finishing hardboard, but has some requirements which affect the manufacture of the board. Variations of these can show up in military specifications or from other purchasing agencies at

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any time. The job should be done by the manufacturer, and, if it is accomplished early, it has a good chance of general acceptance. Later on it is not easy to supercede specifications already established.

THE LOGICAL APPROACH

Right here I would like to suggest that uniform test methods go hand in hand with uniform standards. A common yardstick must be developed by which the products can be checked for compliance with the minimum requirements. So the job is quite a large one. First, the important properties must be established based on their relationship to practical applications. Then adequate test methods must be created for checking these properties. I do not believe it is necessary, however, to create a lot of new tests as many recognized procedures for testing wood and wood products can be adapted to hardboards. Thus the development work can be speeded and the advantage of recognized methods gained at the same time.

Standards must be realistic. They must be workable. Standards are not something to wear in your lapel like a decoration. They are every-day rules of manufacture which are continuously applied in process control, and which finally provide a sound basis upon which users can specify the right products for the right job. Standards should be rigid enough to mean something. On the other hand, they should not be so tight that they are impossible to police or that they create one hairline decision--one borderline case after another.

Perhaps the first specifications should be rather loosely drawn. The first goal might well be to group products with comparable properties and to make sure the term hardboard is limited to materials with established minimum characteristics. With such a beginning, specifications can be formulated or revised as production and use experience are acquired.

Finally, an industry standard should be one which will be met by every panel produced, with a reasonable percentage of falldown allowed for human error. Anything else becomes meaningless because of the impossible nature of its requirements. Producers either certify that their product will comply, hoping not to be checked too closely, or they refuse to acknowledge the standards at all. The true standard becomes the measure of quality of routine production on an every-day basis. It should never be an ultimate goal at which everyone shoots without much hope of consistent success.

Whatever the specification, let's make sure we can meet it day by day, then be prepared to tighten up as experience dictates.

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Some Observations on Tests of Moisture Resistance of Hard-Pressed Boards and Their Significance

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IMPORTANCE OF MOISTURE-RESISTANCE

THE UTILITY of hardboard, or pressed board, is partly determined by a group of properties which can be classified under the heading of moisture resistance. For the purposes of this discussion, the term hardboard includes all pressed lignocellulose fiber or granular particle boards of 0.5 and higher specific gravity.

The moisture resistance properties of a board include the following basic elements:

(1) The speed with which moisture is absorbed under various intensities of exposure to moisture in liquid or vapor form.

(2) The maximum amount of moisture absorbed when exposure is long continued.

(3) The extent to which moisture absorption is translated into changes of the other board properties including (a) appearance, (b) dimensions, (c) mechanical properties.

It is of course principally the last of the three items that is directly reflected in the performance in use of the board products.

In some classes of use, the product is never, or virtually never, exposed to moisture conditions which would bring moisture resistance properties into play. In others, there is a graduation of increasing severity of exposure until the severest condition is reached in which the product is continuously exposed to extremely wet or humid conditions, or probably worse, to alternations of severly wet with severly dry conditions, during the entire expected life of the product. It follows that the interest in moisture resistance properties varies considerably according to the contemplated use of the board product.

RELATION OF MOISTURE RESISTANCE TO USES

To illustrate the range of moisture resistance properties that might be worth considering, a few of the many uses of pressed boards are listed:

(1) Interior Wallboard. Usually free of exposure to water-soaking, but a wide range in atmospheric humidities is encountered. Linear expansion and contraction result in buckling of the board or separation at joints. Thickness swelling of no importance. Resistance to severe degradation of mechanical properties or appearance upon short periods of accidental exposure to wetting desirable, otherwise, effect of wetting on mechanical properties of small importance.

(2) House Sheathing. Usually protected from direct contact with water, but occasional contact possible through moisture condensation in walls or leakage of rainwater through siding materials. Retention of adequate mechanical properties (e.g. stiffness and nail-holding power) under water-soaked condition probably main item of interest. Linear expansion and contraction of little importance.

(3) Furniture or Cabinet Parts. Similar to interior wallboard. Dimensional stability with changes of humidity important. Wet strength properties of little importance.

(4) Counter and Sink Top Covered with Plastic Laminate Surfacing. Subject to wetting at joints; thickness swelling at edges under such conditions important. Otherwise, similar to furniture and cabinet parts.

(5) Exterior Wallboard. Subject to alternate wetting and drying and to wide range in atmospheric temperatures and humidities. Dimension stability (except for low-grade uses), retention of mechanical properties and especially surface smoothness desirable.

It is conceivable that a large number of grades of pressed boards could be tailored to suit exactly the various specific uses of board. However, this would involve difficult manufacturing and distribution problems. It seems that boards are being manufactured for two general classes of exposure: mild and severe. This is exemplified in the standard and tempered or plastic-treated grades of hardboard corresponding somewhat to the interior and exterior grades of plywood.

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TESTS OF MOISTURE RESISTANCE OF HARD-PRESSED BOARDS

PREVIOUS TESTS AND SPECIFICATIONS

Up to the present, the most generally used method of testing and expressing moisture resistance of pressed board products is the 24-hour water-soak with results expressed in percent increase in weight. Reports of tests in the technical and trade literature show no uniformity in the method of conducting this test, particularly in the matter of test specimen size, although a sort of standard was established in Federal Specification LLL-F-311. Most moisture absorption tests reported appear to be based on smaller specimens than the 12-inch by 12-inch prescribed in this standard. The reasons for this are doubtless (1) that much of the testing covers small experimental boards which makes it difficult or impossible to conduct the test on large specimens and (2) that when there are any number of specimens to be tested at the same time, an impracticably large soaking tank area is required.

More recently the American Society for Testing Materials[1] has published a tentative standard for testing building boards in which moisture resistance tests figure prominently. The water absorption test in this proposed standard differs from that in the Federal Standard Stock Catalog (Specification LLL-F-311) mainly in that absorption is expressed in terms of volume instead of weight. In addition to this test, others provided for are (a) mechanical tests on water-soaked specimens to furnish wet-strength data, (b) linear expansion measurements on specimens subjected to high relative humidity, and (c) mechanical tests and qualitative observations of specimens subjected to an accelerated aging treatment involving cyclic wetting and drying effects as well as temperature effects. However, linear expansion, wet strength, and cyclic wetting and drying tests are as yet only infrequently cited in reports on board properties, and water absorption on a weight basis is generally taken as a sufficient indication of the moisture resistance properties of pressed boards.

MORE INFORMATION NEEDED

Except in a very few, or possibly even non-existent, uses of hardboard in which the increased weight of the board upon soaking in water would be important, water absorption figures per se obviously have no significance. When such figures are given as an expression of the water resistance of a board product, it is therefore usually with the implicit assumption that for practical purposes:

(1) there is sufficiently close correlation of the water absorbed in the standard soaking test with the quantity of water that might be absorbed under exposure conditions in use, whether such exposure involves water in liquid or vapor form;

(2) there is sufficiently close correlation of the quantity of water absorbed with its effect on appearance, dimension, and mechanical properties of the board product.

During the approximately twenty years that the bulk of all hardboard in the United States was manufactured by a single process at a single plant a simple, easy-to-run water absorption test no doubt had adequate significance as an indication of the effectiveness of the sizing or waterproofing treatment. Today, pressed board manufacturing is in a rapid state of development, with many different manufacturers and many different processes coming into the picture. The following classification of manufacturing processes illustrates the wide range of types of board being manufactured or in prospect:

FIBER BOARDS
- wet-formed
  - wet-pressed
  - dry-pressed
- dry-formed
  - damp or wet-pressed
  - dry-pressed

GRANULAR BOARDS
- coarse-granule ("Chipboard")
- fine-granule

Boards also can be classified according to the type of binding agent used to accomplish the consolidation of the fibrous or granular wood particles. On the one hand, the binder may be antogenous, or formed from the wood itself by proper pretreatment of the wood and regularion of process conditions. On the other hand, the incorporation of extraneous binding agents, such as any of a large number of synthetic resins or other adhesive materials, may be relied on to hold the particles together. With all the different methods now in use or in prospect for forming and consolidating pressed boards, and with all the different amounts and kinds of binders employed, it would be in the nature of a coincidence if the foremention assumptions regarding the water absorption test proved valid. In view of this situation, it would seem that the interests of present and future users and manufacturers of

[1] ASTM Standards, 1949, Part 4, p. 714, American Society for Testing Materials, Philadelphia.

the many different types of pressed board now - or soon to come - on the market would best be served by more published information on methods of moisture resistance testing and their significance. The data given herewith are submitted as a contribution toward arriving at uniform methods of evaluating water resistance properties of hardboard and toward arriving at a common understanding of the meaning of the results obtained in relation to performance of the boards in their many applications.

EXPLANATION OF THE DATA

The data given here cannot form the basis of final conclusions because (a) the tests were not specifically set up for the purpose of the present inquiry and (b) the number of board samples from which test specimens were taken was extremely limited. However, they can serve to give general indications of the problem and to point the direction in which further investigations can profitably be made.

Table 1 gives a description of the various types of commercial and experimental boards included in the present report. Ten different kinds and thicknesses of the wet-formed wet-pressed fiber boards, two dry-formed dry-pressed fiber boards, three of the fine granular boards, and four of the coarse granular kind ("chipboard") are included.

Table 2 is based on test specimens measuring 3 inches by 9 inches, each value shown being the average of measurements taken on three test specimens from the same board. The measurements involved in the specific gravity determinations were taken after the specimens had come to hygroscopic equilibrium in an atmosphere maintained at 73° F. and 50 percent relative humidity. Thickness swelling and linear expansion were respectively determined by calipering and gaging the specimens after they had come to equilibrium at 20 percent relative humidity, and then at 94 percent relative humidity. The linear expansion gage consisted of a metal jig fitted with an Ames Micrometer Dial (graduated to .001 inch) in such a manner that, when the specimens were placed in the jig, changes in dimension are reflected in the dial readings. The figures in the water absorption column were taken on 2-inch by 8-inch specimens obtained at a different time from different sample boards, but of the same grade and type, and therefore are not directly matched.

The procedures described in the previously mentioned ASTM tentative standard were employed in obtaining the data of Table 3 except that (a) 2-inch by 8-inch test specimens were used in the water absorption test rather than the specified 12-inch by 12-inch specimens, and (b) absorption was expressed in terms of weight increase over the original weight rather than in terms of volume of water absorbed. The smaller specimens were used for convenience, and the weight basis was retained because it has been the customary method of expressing water absorption and no advantage is apparent for changing to the volume basis in connection with hardboards.

Figs. 1, 2, 3, and 4 show graphically the relationship of water absorption figures in Tables 2 and 3 to thickness swelling on immersion, wet strength, linear expansion, and vapor absorption thickness swelling respectively.

From Figs. 1 and 2 it appears that water absorption can be taken as a general indicator of both thickness swelling and wet strength. Therefore, it may be inferred that the water-soaking test has some value in indicating the probably performance in use of boards exposed to contact with water. However, although wet flexural strength (as measured by modulus of rupture) shows a definite correlation with water absorption, the correlation is not close. For example, board number (9), a granular type, has moisture absorption characteristics not much different from those of board (2-AA), a wet-process fiber board, but at the same time it maintains a much larger flexural strength upon water-soaking. Board (2-A), a wet-process fiber board, has about the same moisture absorption as Board (5-AA), a coarse granular type, yet suffers only 1/3 as much drop in strength upon water-soaking.

In Fig. 3 no correlation is apparent between water absorption in the water-soak test and linear expansion with increase in relative humidity. Little, if any, correlation is apparent in Fig. 4 between thickness changes and change in relative humidity. Some types of boards with low water absorption values have high linear expansion and vice versa. Therefore, in those applications where the predominant interest is in linear expansion and contraction, such as the interior wallboard application, the water-soak test would seem to have little value.

While no specific final conclusions regarding the significance of test methods for the determinations of water resistance properties of different types of pressed boards can properly be drawn from the data presented here, certain broad indications are definitely apparent:

(1) No generalizations concerning the comparative water resistance properties of different types of boards such as granular versus fibrous types, or wet-formed versus dry-formed types can be made. A wide range of properties can be found within each type.

(2) The significance of the water absorption test is severely limited as a means of predicting performance of different types of pressed boards in use. Wet strength tests, linear expansion tests, etc., such as those proposed in the ASTM tentative standard could well be employed more widely than is now apparent in the technical and trade literature.

(3) Much further investigation relating to test methods and their significance is desirable.

TABLE 1

Description of boards

Board code number	Board description	
	Thickness --inches	
1-A	1/4	Commercial boards; wet-formed, wet-pressed; interior type
1-a	1/8	Commercial boards; wet-formèd, wet-pressed; interior type
1-B	1/4	Commercial board; wet-formed, wet-pressed; water-resistant type
1-b	1/8	Commercial board; wet-formed, wet-pressed; water-resistant type
2-A	1/4	Commercial board; wet-formed, wet-pressed; interior general-purpose type
2-a	1/8	Commercial board; wet-formed, wet-pressed; interior general-purpose type
2-AA	1/4	Commercial board; wet-formed, wet-pressed; interior wallboard type
2-B	1/4	Commercial board; wet-formed, wet-pressed; water-resistant type
2-b	1/8	Commercial board; wet-formed, wet-pressed; water-resistant type
3-A	1/4	Commercial board; wet-formed, wet-pressed; interior type
4	1/4	Commercial board; fine granular interior type; phenolic resin binder
5-A	1/4	Commercial board; coarse granular; interior type; urea resin binder
5-AA	3/4	Commercial board; coarse granular; interior type; urea resin binder
6-A	3/8	Commercial board; coarse granular; interiór type; urea resin binder
6-AA	3/4	Commercial board; coarse granular; interior type; urea resin binder
7-A	1/4	Experimental board; dry-formed, dry-pressed interior type; phenolic resin binder
7-B		Experimental board; dry-formed, dry-pressed interior type; phenolic resin binder
8	1/2	Experimental board; fine granular; interior type; phenolic resin binder
9	1/8	Experimental board; fine granular; interior type; chemical-induced autogenous binder

TABLE 2

Dimensional Stability of Various Commercial and Experimental Pressed Boards When Exposed to Change in Relative Humidity from 20 Percent to 94 Percent

Board code Number	Specific Gravity	Water Absorption[1] Percent	Thickness Swelling Percent	Linear Expansion Percent
1-A	0.94	13.6	7.5	0.30
1-a	1.04	17.6	7.8	0.34
1-b	1.07	12.0	5.2	0.39
2-a	1.03	9.6	6.1	0.31
2-b	1.07	5.7	7.0	0.32
6-A	0.65	84.3	20.0	0.25
7-A	0.98	20.8	10.3	0.20
8	0.82	31.0	5.4	0.59
9	1.16	12.7	5.2	0.53

[1] 24-hour immersion of 2-inch x 8-inch specimens of same thickness and grade of board, but not from same sample board.

TABLE 3

Water Resistance Properties of Commercial and Experimental Pressed Boards

Board Code Number	Specific Gravity	Water Absorption Percent	Thickness Swelling Percent	Flexural Modulus of Rupture Dry psi.	Flexural Modulus of Rupture Wet psi.	Flexural Modulus of Rupture Loss Percent	Linear Expansion[1] 50 to 97 R.H. Percent	Linear Expansion[1] 20 to 94 R.H. Percent
1-A	0.94	13.6	8.0	3700	2625	29	0.30	0.47
1-B	1.04	10.8	4.2	7250	5520	24	0.16	0.25
2-A	0.97	8.9	2.6	4550	3610	21	0.16	0.25
2-AA	0.92	15.0	5.5	3920	2325	41	0.15	0.24
2-B[2]	1.09	3.8	1.5	7845	7625	3	0.11	0.17
3-A	0.95	24.1	12.2	5410	3040	44	0.24	0.38
4	0.96	20.6	6.6	3200	2100	34	0.38	0.59
5-A	0.69	51.2	9.2	2950	1470	50	0.39	0.61
5-AA	0.81	6.4	4.5	1210	488	60	0.35	0.55
6-AA	0.56	87.2	13.5	1920	867	55	0.11	0.17
7-B	0.96	18.2	6.9	5000	3130	37	0.13	0.20
9	1.14	12.7	5.3	4900	4020	18	0.24	0.38

[1] Specimen measurements made at 50 percent and 97 percent relative humidity. Figures for expansion between 20 percent and 94 percent relative humidity gotten by extrapolation of 50 to 97 percent figures with assumption of linear relationship between swelling and humidity change. The purpose was to reduce these figures to same basis as Table 2 linear expansion figures.

[2] Linear expansion specimen came from different sample board, but of same thickness and kind of board as that from which the water absorption, thickness swelling, etc. specimens were taken.

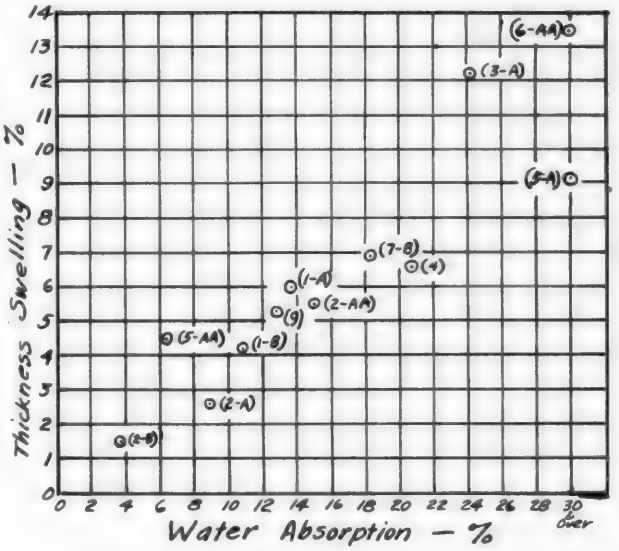

Fig. 1--Thickness swelling versus water absorption on 24-hour immersion.

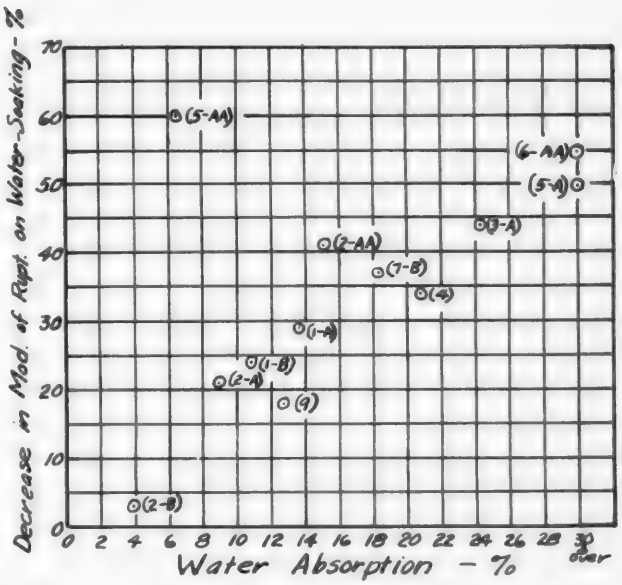

Fig. 2--Decrease in flexural modulus of rupture of commercial and experimental boards versus water absorption on 24-hour immersion.

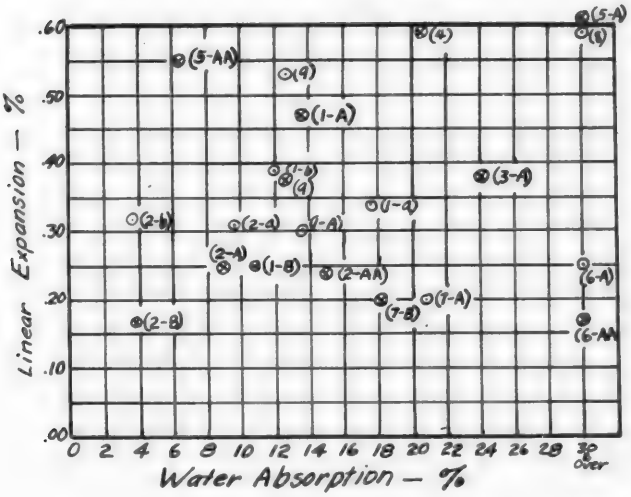

Fig. 3--Linear expansion due to hygroscopic moisture absorption of commercial and experimental boards versus water absorption on 24-hour immersion. (Based on 20% to 94% relative humidity change.)

Ⓣ Table II Data
Ⓡ Table III Data

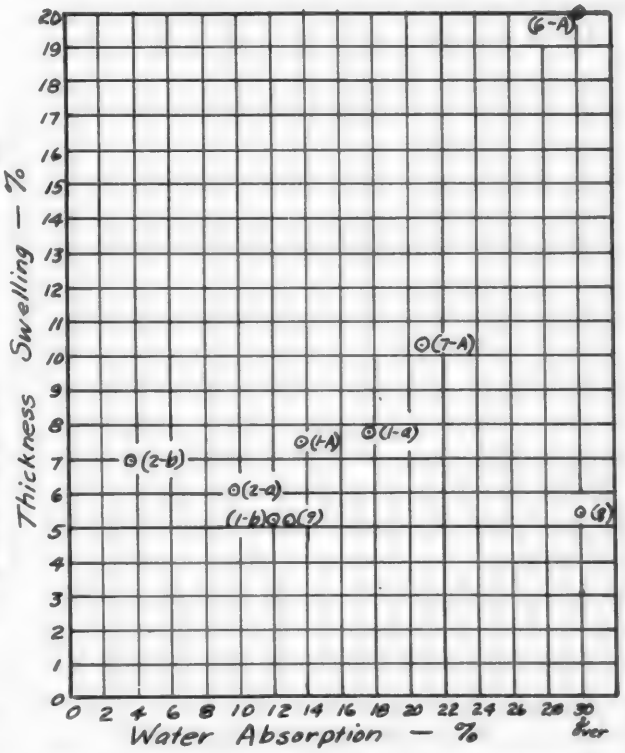

Fig. 4--Thickness swelling due to hygroscopic moisture absorption of commercial and experimental boards versus water absorption on 24-hour immersion. (Based on 20% to 94% relative humidity change.)

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Machinability of Hardboard

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INTRODUCTION

TESTS AND SPECIFICATIONS may be used for two general purposes: (1) for control of quality; (2) for evaluation of a product. The following comments are going to be directed to the second classification; the evaluation of hardboard. Many people visualize the use of hardboard primarily in building construction. However, the past experience has been that a large quantity of hardboard goes into industrial uses and a large volume of this is processed by concerns who specialize in hardboard fabrication. Therefore, any hardboard to be sold in the markets as we now know them must be evaluated in line with its industrial requirements as well as other application needs.

In the industrial shop the user is interested in how the hardboard performs on his saws, drills, shapers or routers, how it punches, or how it performs on his bending mandrels. For the want of a better term I am going to refer to these properties as the machinability or workability of the board.

To date the industry has had to depend on actual use tests to determine the suitability of the board for the various machine operations. There is a very nice problem here for someone to devise and correlate laboratory physical tests with the actual performance on the machines, so that we might more easily specify hardboard properties.

Until someone comes up with the answers to the physical test values, we will have to continue to depend on use tests. Material can be sent out to various industrial users and evaluated on their machines. But this is often not feasible for the development laboratory or preliminary investigations.

At the risk of oversimplifying the evaluation of machining properties of hardboard, I am going to suggest several more or less standardized use tests which should indicate the machining properties. If not used as presented they may suggest a basis for other test methods.

The equipment for these tests is suggested on the basis of general availability rather than from a standpoint of the ideal. If material performs well under these test conditions it should do well in commercial practice.

Presented at meeting of the Pacific Northwest Section, Forest Products Research Society at Longview, Wash., November 14, 1951.

SAWING

Almost all industrial users require good sawing properties. For test, a table saw equipped with an 8-inch or 10-inch blade, operating at about 9000 fpm. is recommended. It should be a cut-off type with three or four points per inch, set to about .007-inch clearance on each side. Adjust the saw 1-1/2 inches above the table and feed the board at approximately 50 feet per minute. Make sure the table slot fits closely to the saw on either side at the cutting point.

For test, set the guide one inch from the saw and saw the specimen twice, the second cut at right angles to the first. Grade the cuts on the following points: (1) ease of sawing - does it feed easily without choking the saw or throwing sparks or burning? (2) sharpness of cut - are there fuzzy or ragged edges, (3) chipping - is the cut free of chipping or flaking on top or bottom of cut, (4) swelling - is there tendency to swell the board at the cut.

A product which will grade well on these points should meet industrial requirements where carbide-tipped saws, specially fitted for hardboard, often are used.

DRILLING

Hardboards are often drilled by industrial users. For test purposes a portable drill or drill press could be used. Use of a 1/4-inch twist drill ground with clearance at a 120° point angle (60° to the drill axis) is recommended. Operate the drill at approximately 2,000 rpm. and drill against a wood block.

As a test make 5 holes 1/4 inch from the edge of the test specimen and grade as follows: (1) sharp clean holes - no fuzziness in holes or at either surface of the board, (2) swelling of board - no thickening at the holes, (3) chipping - no chipping or flaking away on the lower or upper side.

Under these conditions should hardboard drill well with the special drills and techniques available to the industrial fabricator?

DIE CUTTING

Die cutting of hardboards is a common industrial practice and often complicated dies are used. For evaluation purposes, it is suggested that a hole punch be made for a 1/2 - inch hole. The set-up should consist of the punch, a spring loaded stripper plate through which the punch operates and a die. The punch should be .005 inch smaller than the die and the punching will press out through the die. Means for exerting the force on the die can be improvised, possibly using a hydraulic laboratory press.

As a test, punch five holes along one edge of the specimen leaving 1/4 inch of material between the hole and the sample edge. Grade for these points: (1) sharpness of hole - no drawing of fibers to give ragged edges through the hole or at the bottom surface of the board, (2) chipping - no breaking away on the back side, (3) delamination - no splitting of the board, (4) breaking out - punch should not break out material to the edge of the specimen.

Admittedly this is a more difficult test set-up as the skill in die preparation will be reflected in the work. However, it is an important property to check for industrial hardboards and warrants a test set-up.

ROUTING OR SHAPING

The machining of edges to shape or the grooving of surfaces of hardboard is another type of machining operation commonly practiced on industrial hardboards. Again, the commercial operations are varied and the methods numerous.

For laboratory test the use of the home workshop type of shaper or router, operating a spindle at about 8,000 rpm. is proposed. We suggest that a commonly available 3-tip shaped cutter, approximately 2 inches in diameter, be used. Select a pattern which will round the edge of the board on the upper surface and leave a sharp corner on the lower surface.

Feed the sample at about 20 feet per minute, cutting off just enough of the edge to produce the contour selected. Shape two edges at right angles to one another and grade the result: (1) cleannesss of cut - no fuzzy surface on the shaped contour, (2) sharpness of corner on the bottom edge - no fuzzy or chipped condition, (3) rounded upper surface - clean without fuzz or chipping (4) ease of feed - no burning or sparking.

Industrial shapers with small cutters will run at 20,000 rpm. to permit much faster feed speeds.

MACHINE BENDING

Hardboard is often bent on specially built bending machines using heated mandrels. Bends to 2-inch radius are common on 1/8-inch board and sharper bends have been produced.

Laboratory testing is difficult unless a commercial machine such as the Ladon Bending Machine[1] is available. It is recommended that the testing be done on such a machine using 1/8-inch thick board for this evaluation. Use a 4-inch diameter mandrel for the test.

A laboratory machine might be devised. Such equipment should consist of a heated mandrel, means to clamp the board to the mandrel and hold it tightly in contact while the board is slowly wrapped about the roll. The principles used in commercial machines should be studied before designing laboratory equipment.

Three points are important in machine bending: (1) the moisture content of the board should be about 10 percent. Soak the test samples in water - not over 100° F. - until 10 percent is absorbed, (2) the board should be bent on a uniformly heated mandrel at 365° to 380° temperature. For quick bends, temperatures up to 425° have been used, (3) the bending should be at the rate of 100 seconds per 90° bend for untreated 1/8 inch hardboard and 180 seconds for treated hardboards.

Evaluate bends on the following points: (1) cracking - examine the outer surface for small cracks which will show up prominently when the bend is painted, (2) shearing - determine whether the board shows any tendency to delaminate in the bend, (3) swelling - check the outer surface for swelling of fiber due to the soaking operation.

In production, many of the conditions of bending may be altered for the board in question and thus improve its performance. However, the above conditions should prove suitable for evaluating most boards.

I would like to emphasize again that the procedures outlined are not necessarily the best methods, but are proposed on the basis of equipment simplicity and availability. They are suggested for preliminary hardboard machinability testing and evaluation. Actual commercial test runs are recommended for final evaluation.

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[1] Ladon Bending Machine-made by Midwest Manufacturing Co., St. Louis, Mo.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Silvacel Markets and Uses

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SILVACEL is a generic name given by the Weyerhaeuser Timber Company to a complete line of whole-wood fibers. Whole-wood fibers may be defined as individual fibers and fiber bundles composed of substantially all of the original wood substance. Work on the development and marketing of these fibers started in the late 1930's and has been actively pursued since then. At that time there were no established uses for whole-wood fiber.

In many cases it has been hard to say which came first, a new fiber or the use for a new fiber. Quite often, the product engineer, in calling on an industrial prospect has been told: "Your fiber must have many uses but it won't work in our process because--." At this point the product engineer records all the objections, finds out all he can about the use requirements of the finished product, thanks the prospect for his time and the information given, and tells him he will see him again.

Successful product engineering requires a plan of attack very similar to the following:

I. Preliminary Investigations: (A) analysis of use requirements, (B) probability of meeting requirements, (C) probable volume, (D) probable price level -- competitive situation, (E) decision on further development.

II. If the answers to the above questions are favorable, there follows the "final investigation." This would consist of: (A) correlation of requirements with Silvacel properties, (B) test methods and tentative specifications to meet these requirements, (C) choice of product most nearly complying with these specifications, (D) field trials of this product, (E) delineation of deficiencies, (F) correction of deficiencies, (G) taking of orders, handling of shipments, invoicing, and customer service.

The length of time to complete this cycle up to the last item of "taking of orders" varies from several months to several years, depending on many items, such as the cooperation given by the prospect, how near an established product comes to meeting the specific use requirements, and others.

*Presented at meeting of Pacific Northwest Section, Forest Products Research Society, Longview, Washington, November 14, 1951.

If an established product will not meet the requirements but the answers to the other questions are sufficiently favorable, then work is started to develop a whole-wood fiber which will "fill the bill" and a new Silvacel is born. After it has been found satisfactory for one particular usage, other uses nearly always are found for the new product.

In order to discuss specific fibers and markets, it is necessary to go into a short discussion on fiber manufacure. The first item is the raw material supply.

I. Raw Materials: (1) sawmill leftovers, (2) logging culls - partially decayed logs and broken pieces unusable for sawlogs.

Any known western species can be used for most of these products.

II. Process: (a) wood preparation; the raw material is gathered from sawmills or other sources and brought to the fiber plant. The material is taken by conveyor to a commercial chipper where it is chipped and screened. The fines are used for fuel while the over-sized chips are returned to the chipper. Acceptable chips are conveyed to the storage bin.

(b) defibrator; an Asplund Defibrator is used to convert the chips to whole-wood fiber. Many Asplund machines are employed to produce one or two types of fiber. Our Defibrator was purchased as a standard machine but has been improved and modified in many ways so that it will produce several types of fiber with and without chemical additives.

(c) additive system; there are several additive tanks in the additive system -- some equipped with special heating facilities for handling molten material. Chemicals are used with melting points up to 350° F. Metering pumps are used to take the chemicals from the tanks and force them into the fiber system. Jacketed lines are used to keep the high temperature materials from solidifying enroute.

(d) fiber classification; the normal output of an Asplund machine consists of a large percentage of fine fiber ranging down to individual fiber size and a small percentage of shives or fiber bundles. The machine by itself cannot

eliminate the coarse particles, especially when producing at a high rate of output.

For a long time, the market for Asplund fiber was limited because of these coarse particles. In order to serve the markets which would not tolerate these coarse particles, it was necessary to eliminate the unwanted fraction. A method was developed for separating the fiber into various fractions on a production basis.

In some cases the coarse and the fine fractions are marketed separately. In others, the separated coarse fractions are given another defiberizing treatment through a different machine and put back into the original fiber stream on a continuous basis.

III. Products:

a. Whole-wood fiber - No chemical treatment or additives.

Silvacel D-100 - run of the Asplund machine - coarse.

Silvacel D-101 - run of the Asplund machine - fine.

Silvacel D-120 - run of the Asplund machine - very fine.

Silvacel D-122 - this fiber is made as fine as possible in the Asplund and then is separated into coarse and fine fractions. The coarse fraction is further defiberized and then put back with the fines.

Silvacel D-123 - this fiber is made the same asD-122 except that it must be completely stick-free for special uses. Thus, a higher percentage of coarse "cut" is taken off and sold to a separate market while the D-123 is made up of fines only.

As mentioned before, any of the known western woods, can be made into marketable fiber. However, there have been cases where a difficulty preventing a proposed use was remedied by switching to a different species.

b. Whole-wood fiber - chemically treated:

In meeting the use requirements for some markets, it has been necessary to chemically treat the fiber. A good example of this is the home insultation material marketed under the name Silvawood. For this use, the fiber not only must have excellent insulating value (K factor) but must have flame resistance, moisture resistance, vermin resistance, fungus resistance, resilience, and freedom from dust. These properties are imparted by the addition of special chemicals while the fiber is being manufactured.

Other treated fibers are:

Silvacel D-161 - same as Silvawood D-180 except that the fire retardant material is different.

Silvacel H-210 - a partially cooked fiber.

Silvacel Flocs - treated for special uses.

There also are the thermoplastic Silvaloy materials such as Silvaloy D-110, D-111, D-200, and D-300 and the thermosetting Silvaloys which come under the D-400 series.

c. Wood fiber-bark combinations and other mintures; Silvacel D-164 is a good example of a mixture which is manufactured and sold. It consists of a misture of Silvacel D-161 and a special Silvacon bark fraction. More of this product is sold on a tunnage basis than any other single product. Shipments are made regularly to all oil fields north of the Rio Grande. Mixtures of Silvacels and other types of fibers and ingredients either manufactured or purchased are under development and will be manufactured as uses are established.

IV. Markets and uses:

a. Most of the following list are established Silvacel uses. The rest are near commercialization:

Diesel-fuel filter stock, linoleum felt base, roofing felt, saturating sheets, automotive felts, automotive gaskets, special filter stock with beater additives, automobile lubricating oil filters, blotting paper, battery separators, home insulation, cold-storage insulation, water-heater insulation, refrigerator insulation, pulp molding, cold molding, oil well drilling fibers, battery box reinforcement fibers, explosives fibers, welding rod floc.

b. Among the Silvaloy uses are:

Automobile molded arm rests, paint brush handles, molded furniture parts.

Nearly every usage in this list represents from two to four years of co-operative work with a major industrial company in that respective field. An example of this is the one listed as "battery separator."

Over four years ago, the initial call was made on this company to interest them in the use of Silvacon bark products and Silvacel wood fibers. The first products tried did not meet the company's use requirements. However, a co-operative program was set up with all attempts being made to produce the proper product for the firm and with prospective user making a sustained effort to produce a better product using these materials.

It started out sending five-pound samples of products which seemed likely to succeed. When these failed, the fiber was modified and again small samples were tried. Satisfactory results were finally obtained in laboratory batches of separators. Next, a successful pilot plant run was made using a few hundred pounds of material. At this point, the progress was sufficient to warrant field testing of batteries equipped with these special separators. This testing work required a year of life tests under extreme conditions. At the end of that time, the customer was satisfied that he had produced a battery separator which was far superior to the split cedar type most commonly used in good batteries.

Then came the user's decision on how to gain commercial acceptance of the product. After this was settled, a new plant was constructed. Two weeks ago the manufacturer received his first carload shipment (made up jointly of Silvacel and Silvacon bark products) to be used in the manufacture of battery separators. This usage is expected to be a large one.

These stories illustrate the way in which our American system uses co-operative "know how" between companies to produce better products at a saving in cost. It also illustrates how forest raw materials that were previously wasted are being utilized not only at a profit to the manufacturer but also as a service and a new raw material to industry.

One of the Silvaloy uses lists "automobile molded arm rests." Here is the story of an idea which resulted in a completely new method of manufacturing an automobile part. This product required about two years from the time it became an active project until it was put into production. Some of you may have arm rests in your automobiles made from raw materials which originated in Longview. This use is expected to expand to several other automotive parts within the next year. The Company that processes the Silvaloy has many other uses in mind for other industries.

The Silvacel use identified as "diesel-fuel filter stock" is another story. Whole-wood fiber made in Longview, goes to the Midwest where it is converted into filter stock and die cut. From there it goes to the East Coast for assembly into a finished filter. Then it is sold as original equipment and as replacement filters all over the country. It is an even bet that at least one diesel truck which you pass between here and Portland has a fuel filter made of 80 percent Silvacel.

Woodworking Machine Equipment Problems

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INTRODUCTION

THE PROBLEM of operating a woodworking plant at a profit is becoming increasingly difficult today, with ceiling prices setting controls on income and rising costs of labor and materials, taxes, transportation and other factors incidental to the manufacture of wood products increasing general expense.

The amount and kind of machine equipment required has always been a major problem which can be helped, if not completely solved, by careful evaluation, rearrangement and/or replacement. In most cases the added capital investment required serves to materially reduce manufacturing costs and permits the plant to be operated more efficiently and at a greater profit.

There are many ways in which this can be done and the following case-histories may help to solve some specific plant problems. Let us first consider the average millwork plant and compare the conventional type of millwork operation, with its run-of-the-mill machine equipment, with a modern millwork plant which takes full advantage of modern production equipment and layout.

AN OLD-FASHIONED LAYOUT

As shown in Fig. 1, A and B represent a conventional two-story building, with A showing the end elevation and B the front elevation. Both show large swinging doors used for travel of lumber buggies in and out of the plant. The door shown in the upper story is used to lower finished cabinet work down to the motor truck or freight car for shipment.

In the machine layout, as shown at C, (1) is a swing cutoff saw; (2) represents the resaw; (3) a 6-inch moulder; (4) a 15-inch moulder; (5) a rip saw; (6) a planer; (7) a 48-inch roll-feed drum sander; and (8) is an elevator; though many such plants lack this facility. This line-up of machines is the result of the original use of a long line shaft for power, with each machine being driven directly off the shaft. When electric motors were later adopted for power transmission, no attempt was made to change the location of machines to reduce handling costs. This same layout has been used in setting up new mills with the machinery arranged in a similar manner just because that was the way Grandfather did it.

In a large number of woodworking plants today there are too many types of machines and strange as it may seem, too many machines. A competent survey may serve to eliminate those machines whose book value has long since become zero and whose production capacity is close to that figure. Rearrangement of the machines remaining and the addition of a few modern high-speed production machines will effectively eliminate excessive handling and increase plant production.

A MODERN MILLWORK PLANT

The modern millwork plant building is a single-story structure, with the office and cabinet room on the same level as the mill room. In the Fig. 2 end elevation (d) shows the office entrance and (e) the side elevation with the office at the left, followed by the cabinet room and the mill room. Large overhead doors are used at the end (f) of the mill where lumber is discharged into the mill with either straddle carrier or lift truck. The doors at (e) are recessed for weather protection.

In the machine layout, shown at (G), (9) is a straight-line cut-off saw; (10) provision for a second saw; (11) a roll-feed power rip saw; (12) a chain-feed rip saw; (13) a 6-inch electric moulder; (14) either a 10-inch or 12-inch electric moulder; (15) a radial-arm saw; (16) a single-surface planer; (17) a 37-inch 3-drum endless sander. All machines are connected to an adequate blower system.

Part of the lumber entering the mill is processed right through to the cabinet room. Other lumber, particularly air-dried dimension, is discharged through the large overhead doors and is held just inside the mill during bad weather for loading as required.

Stock that requires ripping to straighten for glue jointing or running through the 6-inch moulder (13) or trim that needs sanding can be processed readily at machines (12) or (11) and (9) and on through to (17) If it is to be processed further in the cabinet room, the stock can then pass through the mill to that department.
If, on the other hand, the lumber is air-dried

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dimension, it can be processed at machines (11) and (14) and possibly at (16) and then be discharged through the overhead doors to the loading platform without interfering with stock on route to the cabinet room. Heavy mouldings, such as treads and sills, are run through the heavy moulder (14) and delivered directly to the cabinet room.

Comparing the layout of the old-style millwork plant with that of the modern plant, you will note the endless-bed sander (17) replaces the old roll-feed sander (7) and not only sands to uniform thickness but also handles short stock and all other work previously done on the roll-feed sander faster and better. The resaw (2) is replaced by a combination resaw and rip saw (18) located in a separate building (H) out in the yard and not in position shown. This is a utility machine used to reduce large stock to smaller dimension, usually in small quantities. When this machine is located in the yard, it is more accessible and permits most of the lumber to be handled without entering the mill.

Within the modern millwork plant, everything moves along the line in straight-line production without backtracking. Material designed for the cabinet room does not interfere with air-dried rough or dressed lumber that is processed only in the mill room and is discharged for loading and equipment. Stock ready for shipment does not clutter up the mill as it is temporarily stored in the space before the overhead doors awaiting the arrival of truck or freight car. The savings in materials handling alone is well worth considering as labor has been reduced by this layout as much as 40 percent in many cases.

OLD MILL COMPARED WITH NEW

Let us next consider the difference between the average and modern planing mill. As shown in Fig. 3, (I) and (J) represent a typical one-story building with machines arranged as in (K) to house a planer and matcher (19), a feeding table (21), and a trimmer (20). In the original setup there was no feed table, and being built before the days of fast feeds, the original planer and matcher fed at about 30 feet per minute and the trimmer just about kept up with it. When the original machine was replaced, the present equipment--a 150 f.p.m. planer and matcher and feed table--was installed. The same trimmer was kept, however, which has to be adjusted for every length of board, so no appreciable increase was made in the overall production of the mill.

Installing a modern selective random-length trimmer requires more space than is usually available in the average planing mill and structural changes are often necessary. The best solution to obtain full advantage of reduced costs and increased production possible with this machine is a new mill building adequate for its operation.

What is probably the most modern planing mill in the country was installed at Rochester, N. H., early in 1951. This mill is actually in three sections and produces some 120,000 feet in two 8-hour shifts per day for a planing mill production much larger than the average mill, particularly in the Northeast. The principles involved in its operation can, however, be modified and applied to meet the requirements of a smaller mill with proportionate economy and increase in production.

In this planing mill operation a load of air-dried lumber dotted (27) in Fig. 4 is moved onto an unloader hoist (27) which unloads each layer of lumber onto a transfer chain (28) which delivers it to a kiln car mounted on a lumber stacker hoist (29). A stick layer (30) permits stickers to be placed over each layer and the stacker lowers a course at a time as the unloader hoist raises until the kiln load is completed and is removed to the dry kiln.

After the load is dried, it is run, as shown in Fig. 5, onto an automatic kiln load unstacker hoist (31) which raises the load until the top layer comes into contact with a set of traveling chains (32) which remove the boards, under control of an operator on the platform (35), from the top of the load onto transfer chains (33). The stickers drop onto a transfer belt (34) and the operator removes them to a bunk at the end of the platform. If the lumber to be processed is air-dried, it is fed to the transfer chains (38) over a belt conveyor and bypasses the kiln load unstacker hoist.

Following delivery by the transfer chains, the lumber is next carried through a Stetson-Ross automatic random length trimmer (36) which automatically and smoothly trims the ends with hollow ground saws to even-foot lengths, from four to 24 feet, at the rate of 44 boards per minute, all counted by an electric eye. Defects or wane in any board may be cut out by dropping any saw, or saws, independently by the operator at the switchboard (39). All boards are graded for length, width and thickness at the grading table (37) behind the trimmer and are stacked into unitized lumber packages four feet square for removal by lift truck or straddle carrier.

The final stage of this planing mill operation is conducted in a large building equipped with roof trusses (Fig. 6) so that no posts are present to interfere with machine or handling, as shown at (L) and (M), and machine equipment is laid out for straight-line production, as shown at (N). The four-foot lumber stacks are picked up by straddle carrier in the storage areas and placed inside the mill on a floor deck conveyor (40) which accommodates three loads. The planer and matcher conveyor moves each load off the deck conveyor by means of foot-controlled push-button switches onto a tilting unloader hoist (41) which tilts and raises

the load to feed the boards onto conveyor chains which carry them to the automatic feeding table (42). The automatic feeding table feeds the boards tightly butted into a ten-knife round head Stetson-Ross planer and matcher (43) at a rate of 325 f.p.m.

This high rate of feed requires constant feeding of boards with no lost time between loads to prevent machine down time. A single operator does this by automatic handling and as one load is discharged by the tilting unloader, it picks up the next load from the deck conveyor before all of the previous load has been fed to the planer and matcher. To this point one operator, see circled (X), controls lumber movement.

A maintenance and setup man operates from the grinding and setup room (47) convenient to the planer and matcher, where he grinds all knives and sets and joints them in cartridles, consisting of a yoke with a ball-bearing spindle. When a run is finished at the planer and matcher, he slips out the profile cartridiges and replaces them with new cartridges for the next setup, making a complete setup in a matter of less than 15 minutes.

The top and profile heads and all of the upper feed rolls and outside side head are moved by push-button-controlled motors instead of cranks, and electric brakes are provided on all heads to materially reduce setting up time. Following the setup, the machine operator goes onto his next run and the maintenance and setup man goes back to the grinding and setup room to make ready the next setup.

Dressed lumber passes from the planer and matcher over a belt conveyor (44) where it is inspected and graded prior to entering a tilting reloader (45) which automatically reloads the lumber into four-foot square packages and discharges them at floor level. The load is carried away from the reloader by live rolls onto a roll case (46) equipped with loading jacks to raise the load for removal by straddle carrier.

Thus a load of rough lumber enters the mill by straddle carrier, passes through the mill without a single board being handled manually, except for inspection, and is removed by straddle carrier from the mill after processing. Where it formerly required 36 men in the old mill to produce less than 40,000 feet of lumber per day, the new mill produces more than 60,000 feet per 8-hour day with 18 men. The other 18 men operate another 8-hour shift so that the total production per day is about 120,000 feet, or over 500,000 feet per five-day week.

STARTING POINT FOR IMPROVEMENT

Time does not permit going into detail on other typical wood-working plant operations but I would like to discuss briefly a means of improving conditions at the point of greatest loss in furniture plants, namely between the dry kiln and gluing operations. The layout shown in Fig. 7 has proved very effective in many installations.

The kiln load (48) is first placed on a lumber lift to raise it so the top layer is in line with the tables of two cut-off saws (49). The defects are cut out and the stock cut to length here, and the stock is placed on a conveyor belt (50) for feeding to an automatic jointer (51) which faces the bottom side of the board so that it will lie flat and true. The conveyor (52) then carries it through a single surface planer (53) onto another conveyor belt (54). Four chain-fed rip saws (55) are placed along the belt to rip the stock for defects and to joint for gluing. The jointed stock is then placed on parallel belt conveyors (56) for delivery to two Plycor automatic edge gluers (57) and glued up into panels. This machine equipment arrangement permits the entire cycle of operations, from the rough board to the glued panel ready for further processing, to be accomplished in less than 15 minutes.

No one should jump right into a machine equipment modernization program. Careful study, analysis and planning are required for best results. A plant doing similar work with signal success may be productive of many good ideas. Equipment engineers also visit many plants and know what is going on. Plant supervisory and production personnel often have sound ideas and usually present a practical approach to the problem.

It always pays to start at the beginning. The single trouble spot at shich the greatest saving seems possible may not pay off due to adjustments that have to be made in previous operations. The starting point is usually at the dry kiln or just ahead of it into the mill. Make a tentative plan and general layout of contemplated changes with estimated savings and study it carefully. Then buy the machine equipment most needed. With this installed, you are in a much better position to study the next requirement and the new machinery investment previously made will be building up savings that may partially pay for the next machine. By continuing this practice in a sound, careful manner, a modern well-equipped plant will be possible at a very low cost.

DISCUSSION

ELLIOT MAY (Baxter Whitney and Co.): What is the minimum volume to warrant production in a modern mill?

C. L. BABCOCK (Babcock Machinery Co.): Five to ten thousand board feet of lumber per eight-hour day.

ELLIOT MAY (Baxter Whitney and Co.): Is it necessary to fit each part of a cabinet by hand, or should the equipment machine the parts accurately enough to make this unnecessary?

C. L. BABCOCK (Babcock Machinery Co.): Any good late type equipment will machine all parts accurately enough to require no hand fitting of cabinet parts in production.

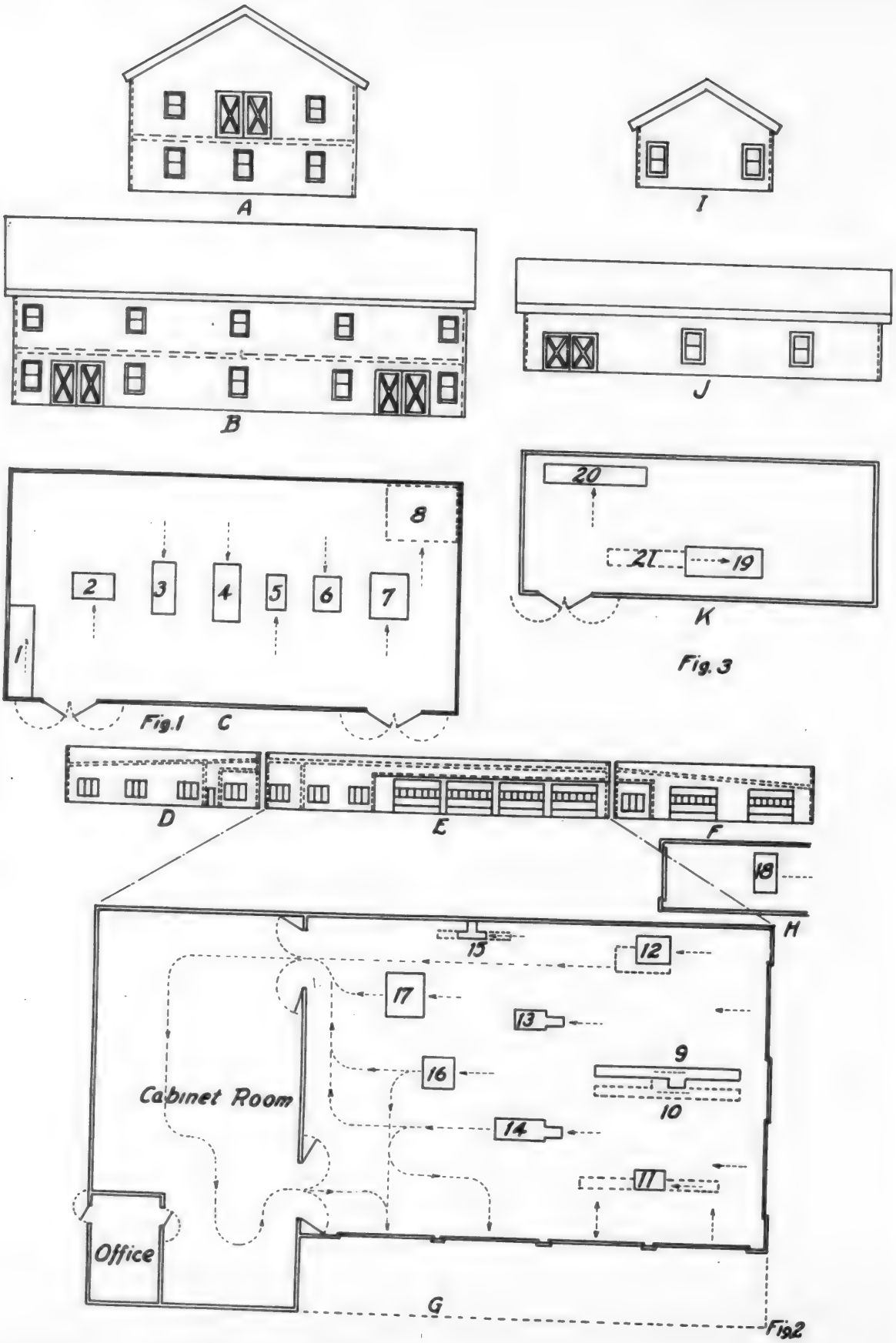
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Fig 2

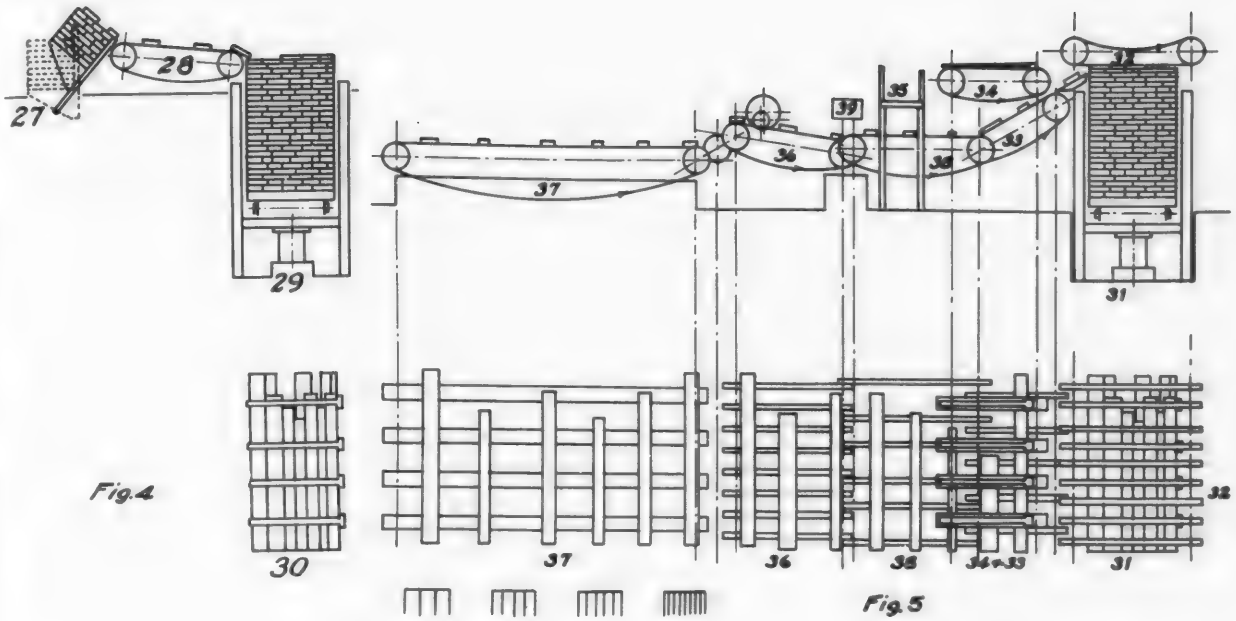
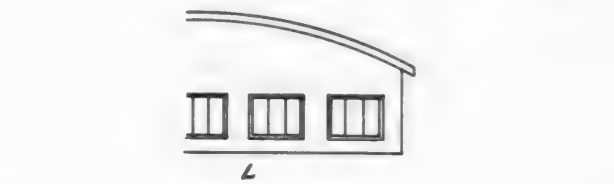


Fig.4

Fig.5



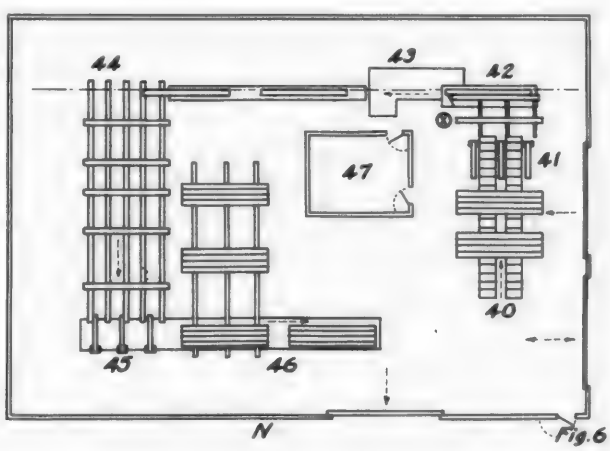


Fig.6

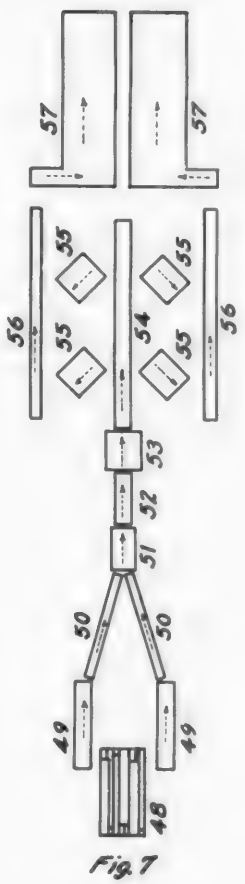


Fig.7

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Lumbering Equipment Problems

FRED C. SIMMONS, Northeastern Forest Experiment Station, Upper Darby, Pennsylvania

IMPORTANCE OF THE AREA

THE 11 NORTHEASTERN STATES, containing about 35 percent of the nation's population produced only about 7 percent of the national total of forest products from its own stands in 1950, and about 5 percent of the nation's lumber; but it is much more important than that in a number of products critically needed for the national defense. The Northeastern lumber industry gets out more than half of the nation's production of such critically important species as white pine and yellow birch, more than 30 percent of the spruce and maple, and 20 percent of the ash and basswood. It supplies only about 14 percent of the nation's pulpwood but this goes in large part to specialty mills that produce a large share of such critical products as waterproof map papers. The Northeast also has about a third of the nation's charcoal industry which is so important in time of war.

PRODUCTION BOTTLENECKS

What is the present state of this regional industry? According to our best information it is pretty healthy, producing at a higher rate than it has in several years. So far problems of equipment and supply have not been too serious. Some items, such as crawler tractors, and tractor parts; large size truck tires, 'dozer blades, zinc for wire rope socketing, planer knives and insert saw teeth and shanks, are increasingly hard to get. So far, however, they usually can be found by shopping around, and the shortages that have developed have not seriously affected production. Even more serious, as evidenced by the discussion at recent sessions of the Northeastern Lumber Manufacturers' Association, are shortages of labor and suitable stumpage. Recent indications are that about 75 percent of the Northeastern loggers are having trouble getting enough labor, making this a critical labor shortage area second only to Alaska. In the Northeast there are probably two major reasons for these labor difficulties in the woods: the unwillingness of Canadian labor to come in under work permit because of the prosperity in that country, and the drift of native woods labor to the better paying jobs in town, particularly in industries with defense contracts. More than half of the Northeastern logging operators also report that they are having difficulty lining up enough stumpage to keep their operations going. Most of them are having to log more remote or lighter stands, which reduces productivity.

Presented at meeting of the Northeastern Section, Forest Products Research Society at Cambridge, Mass., November 2, 1951.

MECHANIZATION OF WOOD JOBS

Both labor and stumpage shortages have been chronic in the Northeastern woods in recent years, but they have been aggravated by current developments. The most obvious way to alleviate them is by greater mechanization of woods jobs. This has been going on more rapidly than most people realize.

Felling and Bucking

At the present time about 70 percent of the felling and bucking of saw and veneer logs on Northeastern logging jobs is being done with power saws. This is close to the national average-exceeded in the West where better than 90 percent of the felling and bucking of these products is being done with power, but considerably more than in the South, where only about 40 percent of these products are cut with power.

On pulpwood and miscellaneous boltwood operations, the Northeast does not show up so well. Only about 40 percent of this smaller stuff is cut with power in the Northeast, whereas 70 percent in the South is power cut and in the West. The principal reason for this is probably that satisfactory one-man chainsaws, adapted to use in the North, have only been available for about the last three years; whereas the wheelbarrow type circular saws, well adapted for cutting pulpwood on the flat open pinelands of the South, have been widely used for more than ten years. Another reason is the large numbers of French Canadians, in this country under temporary work permits on our northern pulpwood jobs. Experience in trying to equip these men with company owned power saws has not been good, and generally they have not been interested in buying their own saws.

Our best data indicate that, on the average, power saws are twice as efficient as hand saws both in the big stuff and the small. The average cutter of sawlogs in the North gets out only about 12 thousand board feet of logs with a hand saw,

whereas the man with a power saw gets out 25 M feet a month. In pulpwood the comparable figures are 23 and 49 cords a man-month respectively.

Consequently the swing to power saws is increasing. Last year United States manufacturers turned out about 40,000 saws. This year it looks as though they will make 140,000. The number of saws in use in the Northeast almost doubled last year and it may double again this year. Most of the increase is in the one-man models.

Yarding

In yarding timber to the roadside, progress toward mechanization has not been so rapid despite the fact that Northeastern timber operators yard longer distances than those in the west and more than twice as far as those in the South. There are three major reasons for the long yarding distances in the Northeast; (1) lack of road building equipment, (2) logging of light volumes per acre that will not pay for much in the way of road building costs and (3) prevalence of direct skidding to the sawmills.

Even with these excessive distances a little more than half of the yarding of sawlogs and nearly two-thirds of that of pulpwood was done with animals.

This picture also is changing. Northeastern timber operators increased their fleet of crawler tractors nearly 25 percent last year, ending the year with more than 4,000 machines. Only about one-fourth of these were equipped with winches or 'dozer blades, and so far there are only about 200 commercially manufactured logging arches or sulkies at work in the Northeastern woods. One reason for this is certainly that none of the major manufacturers have put out a satisfactory sulky for use with tractors of less than 35 horsepower, and over half of the tractors in use in the Northeastern woods are of that size class. A number of small size sulkies have been made at home or in local machine shops, and some of them have been highly satisfactory. Together with a tractor winch they enable an operator to bunch his load more quickly and safely, and to bring in a large load of cleaner logs. Efforts are being made to induce the manufacturers to put out a sulky in this size class. Nationwide, out of a total of about 30,000, there are over 11,000 crawler tractors of under 35 horsepower at work in the woods.

Loading

Loading of logs has also been somewhat slow to be mechanized in the Northeast, probably mainly because of the prevalence of good roadbanks where a log deck can be constructed from which the logs can be rolled on the truck beds. The high cost of commercially manufactured loaders is doubtless a factor also. Forty percent of our sawlogs are loaded manually, about ten percent are loaded with animal power, and 50 percent are loaded with mechanical equipment. But hand loading is hard dangerous work, and it is slow. It increases the idle time of the hauling trucks. Northeastern timber operators increased their use of commercially manufactured cranes and shovels about 15 percent during 1950. In addition a large number of homemade devices, ranging all the way from a block hung in a tree to a hydraulically operated crane mounted on an old truck chassis are in use. Of the 20,000 trucks used in hauling logs and bolts, about six percent are equipped with winches useful for self-loading.

Hauling

In contrast with yarding, Northeastern sawlog operators have about the shortest hauling distances of any section of the country. About a fourth of the sawlogs are skidded directly to the sawmill, with no hauling involved, and the average hauling distance for sawlogs is about 12 miles. On the other hand, Northeastern domestic pulpwood is hauled an average of 55 miles and veneer logs an average of 71 miles (the longest average distance for any product in any section of the country). The major part of this hauling is done by the truck although about one-third of the veneer log haul, and more than half of the pulpwood haul is done by common carrier railroad. The company-owned logging railroad has almost disappeared from the Northeastern woods.

The most striking thing about the fleet of 20,000 trucks used in hauling Northeastern timber products is that about a third of them are over ten years old. Northeastern loggers, by and large, have not bought many new trucks in the past few years. Only about a third of the 3,000 trucks they purchased in 1950 were 1950 models. This points to a big maintenance or purchase problem during the next few years.

Most of the timber products in the Northeast are hauled on the truck bed. Only about 1,200 trailers are in use. The most poplar truck size is in the 16- to 19-thousand-pound-gross vehicle weight range. This is largely due to the narrow widths of public roads being traversed, bridges of limited capacity, and hairpin turns. However, it is a big improvement over the 1-1/2 ton trucks of popular makes formerly used and there is a definite trend toward somewhat larger trucks as roads are gradually improved.

Eliminating Bottlenecks

It is obvious from these facts that Northeastern loggers are becoming more and more dependent on mechanical equipment to carry on their

business. As labor becomes scarcer, and higher priced, and the stands being logged contain less and less volume per acre and become more remote, this dependence on mechanical equipment is bound to increase. Shortages of mechanical equipment that are developing, and of parts necessary to maintain them and supplies necessary to keep them running, will be much more serious than they were during the last war.

There are many things than can be done to alleviate such shortages. Most of them depend on better training of woods labor and better supervision of woods jobs. Preventive maintenance of machinery, involving regular cleaning, tightening, inspection, and lubrication will keep equipment running more steadily, and eliminate most of the serious breakdowns which call for expensive and time consuming repair jobs and quantities of scarce parts. To be successful such a preventive maintenance program must be the responsibility of everyone on the job, not the supervisory personnel alone. Every machine operator must be trained to keep his equipment in shape, and to do simple repair and maintenance jobs. He should be instructed to report any indications of something serious going wrong to his supervisor. Equipment must be properly used, not chronically overloaded or asked to do jobs it was not designed to handle. Both of these practices are far too common Northeastern woods operations. And substitutes for scarce supplies or parts will have to be developed. We had some experience with these during the last war, but we are probably going to have to do a lot more this time. As socket metal for wire rope becomes scarcer, we will have to do more splicing. If copper tubing can't be found we will have to use plastic tubing and know how to install it so that it will not crack in a few days from excessive vibration. As natural rubber for tires becomes scarcer we will have to do more recapping and take extra precautions against overheating of synthetic rubber. There are literally hundreds of ways in which scarce materials can be conserved, and productivity maintained.

SAWMILLS

The equipment situation at Northeastern sawmills is similar to that on woods jobs. There has also been an increase in mechanization. The old steam engine power plant has practically disappeared, particularly in the smaller mills, and internal-combustion diesel or gasoline engines, or electric motors have come in to take its place. A great deal of higher speed, ball- and roller-bearing equipped machinery has been installed, along with conveyor handling systems, and electric, pneumatic and hydraulic devices to reduce the amount of manpower required to make lumber and to do the job better, more easily and more safely.

By and large, despite the poorer quality of the logs with which they are supplied, Northeastern saw mills are turning out a better product, more accurately sawed, graded, and dried. In 1950 Northeastern sawmills air dried nearly half of their product, but kiln dried and dressed only about 10 percent. They cut only 3 percent into dimension or other specific products.

Nationally 28 percent of the lumber produced is kiln dried at the sawmill, and 54 percent is dressed. The importance of these processes is better realized at mills remote from their markets, and confronted with high shipping costs.

At the end of 1950 there were about 200 forklift trucks in use at Northeastern sawmills; practically all of them bought in the last four years. There were also about 50 straddle-lift trucks, of which only 10 were over four years old. Since there are only about 600 sawmills cutting more than a million feet a year, this points to a definite trend.

The number of stationary industrial engines is just about equal to the total number of mills. About 7,000 of them are in use. Over half are in the 100 to 500 horsepower range. About a third of them are over 10 years old.

SUPPLIES

The current usage of scarce supplies in this relatively small segment of the national sawmill industry really runs into big figures. In 1950 Northeastern mills used about 80,000 boxes of insert saw teeth, and 10,000 boxes of shanks. They installed about 15,000 lineal feet of new bandsaws, and 5,000 new circular saws. They used about 40 tons of steel strapping.

In both logging and mill and yard equipment, Northeastern timber operators used about 20 million gallons of gasoline and 10 million gallons of diesel fuel. They mounted about 50 thousand new tires on their equipment, about half of them in the 8.25 inch diameter class and larger.

MANPOWER

About 70 thousand men were employed on Northeastern logging jobs last year, for an average of about 6 months each. Only about 6 percent of this labor is in occupations classified by the U. S. Department of Labor as unskilled. Fellers and buckers constituted about 50 percent of the total, about a third of whom

were using power saws. Twenty percent of the total were classed as truck and tractor drivers.

The major problem of Northeastern loggers, now and in the immediate future, will be to keep this labor on the job. Further mechanization would make it possible to get along with fewer men, and to pay higher wages to those that remain. The example previously given, of twice as great production from fellers and buckers working with power saws, indicates the possibilities along this line. Similar increases in productivity per man-month can be made by using more tractors for yarding and more power loading devices. There are many obstacles to such a swing to mechanized methods. One, which is bound to become increasingly important, is the scarcity of mechanical equipment and parts and supplies to maintain it. Another is the type of woods labor we have available, much of which is not of a caliber to use mechanical devices successfully. Another, of course, is the cost of changeover. All of these are real obstacles, but they are overweighed by the disadvantages of trying to continue with hand and horse methods. The obstacles have been overcome by a large number of our logging operators, and will almost certainly have to be overcome by others if we are going to be able to continue to get out the products of our Northeastern woods that are so urgently needed by the Nation and the World.

DISCUSSION

A. B. RECKNAGEL (St. Regis Paper Co.): Would you comment on the prejudice against the use of power saws in pulp cutting due to the rough ends created and the pulling of splinters?

F. C. SIMMONS (NE Forest Expt. Station): There has been some objection in the past to wood cut with power saws at pulpmills. This was primarily due to poor fitting of power-saw chains. If teeth were out of line or of uneven height the wood was left with very rough ends. One make of chain, which we won't mention here, is notorious for leaving a rough cut which cannot be corrected by better fitting of the chain but with all the other makes care in chain maintenance will leave relatively smooth ends. The narrower chains used on present day one-man saws are better than the heavier coarser two-man saw chains. Power saw cutting is definitely here to stay in the pulpwood business. I believe 70 percent of Northeastern pulpwood will be cut with power in 1952.

The objections to rough ends arise from two causes. With a rough end it is difficult for the cutters to mark their initials on the ends of the bolts to make claim for pay purposes and for the scalers to make the marks they have been accustomed to for showing progress and results. There has also been some complaint about splinters from such ends at the mills, which do not chip or cook properly and which show up as shives in screening. Neither is too serious with a properly fitted chain.

JAMES HAMILTON (U. S. Bobbin & Shuttle Co.): Is there an economical debarking method for use with Northeastern hardwoods like maple and birch for later use as pulp?

F. C. SIMMONS: I am sorry to have to report that there is no completely satisfactory mechanical way of debarking hardwoods as yet. Hardwood bark is generally harder and more difficult to remove than that of softwoods, and the sticks are apt to be more crooked and rougher, making it a difficult job to debark these species by methods adapted to softwoods. A lot of people and agencies are working on the problem, however, using a number of different approaches, and perhaps the answer will be found soon.

Hardwoods can be satisfactorily debarked in a drum barker, but it has to be a bigger sturdier machine than that used for softwoods due to the additional weight, and the process has to run about twice as long as for softwoods. In the winter a hot-pond treatment definitely has to preceed drum barking of hardwoods. And due to the longer treatment and additional weight there is more loss from brooming of the ends of the drum barked bolts.

The most promising method of getting the bark off hardwoods developed to date is chemical treatment of the standing tree during the ordinary peeling season. At periods, varying with species, of from three to six months after treatment the bark is so loose that about 85 percent of it falls of during felling, skidding and hauling. Three Northeastern pulp companies are using this method on a considerable scale.

MR. SMALLEY (Eagle Square): Is there an economical method of debarking short hardwood logs?

F. C. SIMMONS: It would definitely be advantageous to debark short logs prior to putting them through the sawmill. The principal advantage would be that the slabs and edgings, which would be free of bark, would be salable at a much better price than that obtainable for fuelwood. These bark-free slabs and the bark-free sawdust would also be a more promising

raw material for many other uses, such as plastic filler, hardboards and even roofing felt.

The problem of sawing would also be lessened, primarily because the bark with its embedded dirt and gravel would be gone. One mill reports that their saws last from three to five times longer between sharpenings when used with bark-free logs. Embedded metal and defects are easier to see.

I believe a log barker, if one can be developed, would have many advantages over a barker for four-foot bolts. It would certainly promote integration of saw and veneer log, and pulpwood procurement, with attendant advantages to all three industries.

F. R. MacDONALD (Mountjoy Timber Co., Ltd.): Is there any equipment to replace the horse for logging?

F. C. SIMMONS: There is a variety of equipment which is fast replacing the horse in the woods. The most generally useful in the Northeast is the crawler tractor, in its various forms and with a variety of accessories. Tractors are available in sizes ranging from 8 to 120 horsepower. Most generally useful under our conditions are those in the 25 to 50 horsepower range, equipped with a winch to enable them to reach into rough or rocky places where the machine should not be taken, and frequently with an arch or sulky to lift the front end of the load off the ground.

Complete cable skidding rigs, with from one to three drums, have their field of usefulness also, and I feel sure we are going to see a lot more cable logging in the Northeast in the next few years. Light, fast, mobile rigs are being developed in the West for harvesting pulpwood, and in Europe for a variety of really tough conditions. The recent importation of the Wyssen-cableway from Switzerland to make possible the logging of rough upper slopes in the Adirondacks is an example.

By and large the wheel tractor has not proven generally useful under Northeastern conditions. Most of our country is too rough and rocky for its safe and economical use. It is a good tool on some of the more level country along the coast and on some of the farm woodlands.

F. R. MacDONALD (Mountjoy Timber Co. Ltd.): What is the value of the LeTourneau Skidder in the Northeast?

F. C. SIMMONS: The LeTourneau Company had its engineers in this territory for some time investigating woods all the way from western Pennsylvania to eastern Maine. Their general conclusion was that the Northeast presented them with little opportunity for a market for their equipment in its present form, or any adaptation of it. The present Tourna-dizer of course is too big and expensive for most of our wood operators. A smaller model would have the same objections as the other wheel tractors, too high a center of gravity and too little traction.

More promising are the Bombardier conversion tracks for Ford and Ferguson tractors. These have become very popular among the smaller operators in the woodlot regions of New England and New York. They give them a better rig for work around the farm, like snow plowing and hauling manure in the winter months, as well as a useful tool for light logging in the woods in these same months and other seasons as well.

QUESTION: You seem to recommend more, rather than less mechanization of woods jobs, in the face of present shortages. Where is the additional machinery coming from?

F. C. SIMMONS: That's a good question. There's no doubt that equipment and supplies will be very scarce during the next few years. I doubt very much if they are as scarce as manpower and horse feed. Eighteen percent of our present labor force in the woods is of draft age. We will certainly lose a large portion of these boys, and in addition we will probably continue to lose more of the older men to other industries and through retirement. Hand methods, with their special skills, hard work and low productivity, do not give us much of a chance to compete with other industries, to help keep good men on our logging jobs, or to attract new men such as mustered-out G. I's.

There are plenty of chances to increase mechanization with the equipment we now have. Much of our equipment is now used a small part of the work year. Instead of letting a tractor, shovel or crane sit idle in the woods or the barn for nine months of the year, a better scheduling of our jobs and a more general practice of renting or loaning unused equipment to other operators might easily result in use for eight or nine morths. Building or buying a low, tilt-bed trailer would make it easy to shift such equipment from job to job. Frequently there is less deterioration of equipment while it is working than when it is sitting idle.

Some new equipment will certainly continue to be available for those who have real need and use for it. Used equipment will probably be even more easily found. Northeastern loggers are no strangers to purchase of used machinery. Of the 2,800 trucks they bought last year only 1,000 were 1950 models. Purchase of used equipment, of course, intensifies the importance of the maintenance problem. The whole problem calls for application of some of that vaunted Yankee ingenuity.

QUESTION: Is anything being done by governmental agencies or trade associations in training in the equipment and supply conservation measures you recommend?

F. C. SIMMONS: Not a great deal in the Northeast as yet. There were several such training programs during and immediately following the last war. The Forest Service conducted a series of Crossroads Sawmill Conferences, designed to help small sawmill owners keep their mills running more efficiently. They were quite successful. It also conducted a training program for German and Italian prisoners of war in woods work. The War Production Board devised three very useful courses: Job Methods Training, Job Instruction Training, and Job Relations Training, which were presented at hundreds of sessions to every sort of industry, including the wood using industries. Since the war some of these have been continued. The American Pulpwood Association has my old associate Harry Jefferson as its training officer and he has done excellent work throughout the country. The Vermont and Maryland Forest Services continue small sawmill specialists on their payrolls. In addition individual industries continue to supply training services. In recent years I have had occasion to call on tractor manufacturers, chain saw manufacturers, and wire rope manufacturers for help in training woods bosses in the care and use of their products, and they have given such help willingly and very effectively.

There's no question that in the light of the present and probable future conditions, such training programs should be stepped up and intensified. A number of people are available who know how to do the job.

QUESTION: Must we resign outselves forever to logging lighter and lighter stands and more defective and smaller timber?

F. C. SIMMONS: There are probably a number of people here better qualified than I to answer that question but I'll take a shot at it. I certainly hope that we can look forward to better stands and better qualities of timber in the not too distant future. These are the aims of good forest management but I'm afraid we will have to admit we are getting far too little of it to date. The good second growth and cutover stands we have now are largely the result of what H. H. Chapman calls "accidental forestry." Partial cuttings for particular species or products have accidentally served as thinnings or improvement cuttings, or have provided conditions for good advance reproduction. Heavy cuttings in stands with such good advance reproduction, or at the time of a heavy seed year have resulted in some excellent second growth. Patches and spots of such good second growth can be found, particularly in our better timber growing areas such as the Berkshires and the Allegheny plateau.

We have an exceedingly complex forest here in the Northeast. We not only have a large number of timber species and types but also a tremendous variety of soils and growing conditions. Measures that will keep the right species growing on the right sites in the right densities and compositions are necessary to effect improvements, particularly in timber quality. The simple minimum forestry measures to maintain productivity so widely advocated and which several of our States are enacting into law will not do it except in spots. Any simple formula, such as "Keep out fire" or "cut to a diameter limit" being applied by many of our landowners will not do it, except in spots. Improvement of our timber stands in quality and quantity calls for application of scientific forest management practices, by qualified professional men, on a relatively intensive basis. And it calls for a lot of additional research. We are getting a mere smattering of this kind of management now on the National Forests, State Forests and some private holdings. We need a lot more of it.

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The Integration of Pulpwood and Lumber

W. ARNOLD HOSMER, Professor of Business Administration, Harvard Graduate School of Business, Cambridge, Massachusetts

INTRODUCTION

A HARDWOOD stand mature enough to be operated for saw logs includes raw material for both lumber and pulpwood. The two products always occur together except that a young stand in the late pole stage may contain only pulpwood. This paper is concerned with hardwood stands which contain sawlogs and therefore may yield both lumber and pulpwood.

The two products are related at every stage of operation from the original layout of the cutting site and road construction to logging, relogging, lumber sawing, and manufacture of the lumber into finished products. If full advantage is taken of the possibilities in integration the cost of logging operations can be reduced and the competitive position of the firm doing the cutting can be improved. This applies whether the logging is done by a lumber operator with pulpwood as a by-product or a pulpwood operator with lumber as a by-product. The interests of firms on the lumber side and on the pulpwood side are not opposed; both can be benefited by integration in the harvesting of forest stands. Furthermore, if this work is well conceived and well carried out on a basis designed to be profitable, it will facilitate the type of sustained yield forestry in which we are all interested.

THE ACCESS ROAD FACTOR

Let us take the matter of roads. Too little attention has been paid permanent access roads--roads which can be put back into usable condition with relatively little expense 8 or 10 years hence if it is desired to go back for another cutting. They need to be laid out with great care, realizing that roads become an important part of the capital value of a stand. Depending on the site they may be usable only when frozen, or only in dry weather, or in some instances they can be used at all seasons except the break-up season in the spring.

The bulldozer has changed the whole road building picture and integrated use changes it still further. Of course the cost of roads depends on the site - both the cost per mile of road and the length of road required per acre. In regions interlaced with hard surfaced public roads, probably 50 percent of stands can be provided with reasonably complete access roads, gravelled in soft spots, for $1,800 per mile at 17 ft. per acre or $6.00 per acre. Some roads are essential; added expenditures on good access roads can often be more than recovered from reduced cost of operation and added material obtained. The balance of advantage probably lies in greater expenditures than we have been making on access roads. One might go further and say it is essential to lower cost and higher profitability in woods operations.

When a road system is once installed to get out the main crop, then road costs do not need to be included in deciding whether to bring out additional material. The incremental costs in bringing our additional increments of material do not need to include costs in preparing the site. Costs applicable to additional increments are only those directly applicable, which vary with additional recovery.

PRELOGGING AND RELOGGING

For these reasons relogging is likely to be profitable. By relogging is meant going over the site cutting up tops for pulpwood, taking injured trees, cutting low-grade wolf trees not selected for saw logs and doing thinning where this is called for in a pole stand. The objective is to carry through the original cutting plan to completion, using sound forestry judgment in leaving the stand in the best condition for future sustained yield. This relogging can give substantial yields of pulpwood.

In the Douglas-fir region on the West coast Weyerhaeuser is using five logging operations. To be sure this is block cutting, but the principle is the same. In the first pre-logging small trees 12 to 24 inches in diameter are cut and hauled out by winches on tractors. Then larger trees, 24 to 42 inches are cut and removed likewise with winches. Unless these smaller trees are removed first they are broken up when the big trees are felled. In the main logging operation the big trees are taken, typically with a spar tree and high line. This is followed by two relogging operations, the first to get saw logs and the second to recover broken logs etc. for pulp. They find this somewhat complex process profitable.

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At Crossett, Arkansas, they do regular relogging for pulp after removal of saw logs. Under New England conditions the profitability of woods operations can in most cases be increased by systematic relogging for pulp. Lumber and pulpwood occur together; the cost of both can be reduced by operating for both products.

DEAD HEAD "SAWLOGS"

Throughout New England logs appear on the log decks of saw mills that should never by sawed. If a log doesn't yield enough in lumber to pay for the cost of sawing it is worthless on the log deck. If it yields only $20.00 per M after the costs of sawing it is still not worth putting over the saw. A profitable saw mill typically makes money on its good logs and almost every mill loses money on the lowest grade of logs sawed. This means that the owner would be better off if he culled incoming logs rigidly and sold the culled logs for pulp. Is it a fair guess that 20 percent of the logs sawed in New England reduce the profit of the operators?

The reasons why poor logs appear on the log decks are not far to seek. Many stands are operated for only one product, for instance saw logs, and any logs that are reasonably passable are brought in. Second, logs are very difficult to grade. Furthermore, many mills have difficulty getting logs enough to operate and saw low grades of material to carry their overhead. There are probably too many small mills the owners of which don't know their costs. It probably would be an advantage to the owners themselves and to the industry if 10 percent of these mills were eliminated. The best logs they now use would help the other mills to keep up their volume.

SAWLOGS IN THE PULPWOOD

Just as poor logs appear on the log decks of saw mills, so some high-grade logs appear in the material sold for pulpwood. The amount is not large, not over 10 percent. One occasionally finds veneer logs in pulpwood. Most of the good saw logs are selected and sold for the higher prices they will command as saw logs. But pulpwood operators are not always familiar with log grades or with the market for logs. And some stands contain so little high-grade material that the operators don't bother to select it and sell it separately. In any event some sawable material gets into pulpwood, but the amount is not as large as the pulpwood component on log decks.

This discussion has been concerned with purchased pulpwood. For hardwood operated by pulp companies themselves there has been a tendency to take everything on the stands for pulp. With current high prices for lumber the pulp companies are missing an opportunity to reduce their cost of pulpwood if they fail to segregate high-grade logs and get them headed for the lumber market. The best companies in the South and West have found it profitable to segregate saw logs. Interesting developments along this line are beginning to occur in New England.

To repeat, lumber, logs and pulpwood occur together. The costs of both products can be reduced by operating for both products, especially in a careful and systematic segregation of saw logs and pulpwood.

NEW METHODS FOR HARDWOODS

The integration of lumber and pulpwood end uses goes further - into the actual manufacture of lumber from hardwood logs. A number of mills have worked out methods which give very interesting results in yield and quality of lumber. An attempt is made in this paper to bring together some of the significant current developments in the form of a description of a method of manufacturing and selling hardwood lumber which may be standard practice in New England in five to ten years.

The following paragraphs describe a method of handling hardwoods which brings together some of the most significant current developments. Some of the steps may impress you as radical and possible ill advised. If so, your raising questions about them would be appreciated. Our objective is profitable operation in the interest of the firms in the industry, and of the entire region in a conservative handling of hardwoods as a national resource.

In the first place all hardwoods should, in the writer's opinion, be barked before sawing. The slabs, cores, board edgings and trimmings then become available for sale as pulp. This procedure has become standard practice on the Pacific Coast. It is likely to be standard practice here within ten years and for the best firms within five years.

Two technical problems need to be solved. One is an effective barker, cheap enough to warrant installation in a medium sized saw mill and cheap enough in operation so it will be profitable to bark logs and sell the solid waste for pulp. The ingenuity of New England manufacturers has solved more difficult problems and can solve this one. Second, improved means are needed for making a high quality of paper pulp chips from saw mill waste. This problem is in process of solution.

The solid waste probably will be chipped to pulp mill specifications at the saw mill and shipped to the pulp mill either by rail in covered hopper cars, or in trucks with hopper bodies as large as trailer vans. One pulp mill on the West Coast receives 140 tons a day of chips hauled by one truck loaded from overhead bins and getting a 5-minute turn around at each end of its haul.

The profitable sale of solid waste will change the entire picture of saw mill operation and of lumber markets. When a sawyer gets down to a core containing No. 2 and 3 common he is likely to pull the core off the saw and send it down the chute to a chipper.

Ten years from now probably 50 percent of hardwood logs will go over a cutoff saw before they go the head rig. Some outstanding results have been achieved by cutting hardwood for length and sawing on a bolter. The work of the Moosehead Manufacturing Company at Monson, Maine is especially successful. All the lumber for their line of high grade furniture is bolter sawed.

Crook can often be removed from a log by cutting it to 4-, 6- or 8-ft. lengths. Furthermore many logs contain one section of high grade saw log material and another section which should go for pulp. The time of the head rig, edgers, trimmers and lumber handling facilities can be saved by sawing only that section which warrants sawing. Of course many logs are sawable for their entire length.

POSSIBILITIES IN SHORT LENGTHS

Many of you have been saying that short lumber must be sold at a discount and that this will destroy any possible profit. The writer would like to lay before you the conception of standard short length lumber, cut clear, as a means of marketing hardwood.

Suppose that lumber from short logs, after kiln drying, is put through cut-off and line saw operations and cut to standard lengths and random widths 2-1/2 inches and up. The standard lengths might be 14 to 24 inches by 2-inch intervals, 24 to 72 inches by 3-inch intervals and 72 inch and above by 6-inch intervals. The lumber should be entirely clear with defects either cut out or the entire piece consigned to the chipper.

Lumber of one length, for instance 45 inches, would be strapped on a skid and handled into or out of a truck or freight car and in the plant of the purchaser by fork truck. Possible 500 ft. would be strapped on a skid. The savings in handling costs and freight rates would be substantial. Furthermore cut-off and line-saw waste would be developed at the producing mill. If this mill had facilities for chipping, the waste developed in cutting to a rigid quality standard could be sold for a substantial sum as chips.

In a furniture factory over 80 percent of the lumber is used in lengths of 48 inches or less. The longest common cut is for bed rails at 77 inches. All of the lumber used in furniture can be cut from a 7-foot log.

The central fact about this clear short length lumber is that the waste percentage in the user's plant is reduced. True, there would be waste if a 42-1/2- inch dresser top were cut from 45-inch stock, but the percentage in this instance would be only 5.9 percent on the material used as a base. The cut-off and line-saw waste in cutting FAS, Selects or No. 1 Com. and better would run many times this figure. Furthermore, there is no guarantee that the cuts obtained from No. 1 Com. and better will match the cutting schedule. Of course, some waste would develop in manufacturing beyond the original cut-off waste given above as 5.9 percent, but this is likewise true if the cuts are obtained from long lumber.

Samples of yellow birch prepared by the method described above are available here for your inspection.

What is this lumber worth under the present market structure? Yellow birch lumber 4/4 is quoted as follows in the Commercial Bulletin for September 15, 1951. These prices are given f.o.b. the producing saw mill.

F A S	$230 - $245
Selects	220 - 230
No. 1 Com.	130 - 150
No. 2 Com.	70 - 85

We should bear in mind that the reason for buying lumber of whatever grade is the production of cuts of the length required in the finished product. The longer cuts are more difficult to obtain. The following figures show the lengths of clear stock obtained in experimental sawing of 4-ft. bolts.

Length Inches	Percent	Cumulative Percent
48	4.9	4.9
45	41.3	46.2
42	35.0	81.2
39	3.7	84.9
36	5.0	89.9
33	.6	90.5
30	2.6	93.1
27	.1	93.2
24	3.5	96.7
22	---	96.7
20	.1	96.8
18	2.2	99.0
16	1.0	100.0
	100.0	

It is notable that 90 percent of the yield of clear stock was in boards 36 inches or more in length even though the material sawed was 48-inch bolts. The indications are that if 8-foot logs had been used the lengths of the final cuttings would still have been heavy on the long side. Even with 4-foot bolts the percentage of long cuts is greater than that called for in cutting schedules for the manufacture of high grade furniture. With an admixture of 8-foot logs of similar quality this material would have provided all of the lengths needed for fine furniture, probably with a surplus in the longer cuttings.

This standard clear lumber is not dimension stock. Dimension stock is cut in the plant of the supplier to lengths prescribed by the buyer. The salability is thus limited. In the writer's opinion the final cut should be in the hands of the user where he can control it as he sees fit. With clear short lumber cut to standard lengths the user can buy the lumber he wants in the lengths he needs and keep his waste factor at a minimum.

It is to be hoped that the discussion period will afford an opportunity for expressions of opinion as to the proper price for this material in the present structure of the hardwood markets.

Of course a large portion of our hardwoods should continue to be sawed in 12- to 16-foot logs and sold by standard hardwood grades. But for 40 to 50 percent it may well be advantageous to cut the logs to length first, depending on what is in the log, and manufacture the lumber in standard lengths of clear lumber, carefully kiln dried, with rigid quality control, and packaged for ease in handling. Material of this nature might sell to advantage as far west as Grand Rapids.

The standard long-carriage head rig is to come extent as anachronism, a partly obsolete device. It developed when the grade of logs sawed was what we now think of as veneer logs and other logs were left in the woods. Now we need to adapt manufacturing methods to the material at hand. New England hardwood stands contain some of the most beautiful lumber in this country, but it needs to be properly manufactured.

Throughout this paper emphasis has been placed on the integration of lumber and pulpwood end uses in hardwood. Both products occur in the same stands, use the same roads and even exist in the same log. The profitability both of lumber and of pulpwood firms can be increased by the joint use of both products and their joint use can likewise be made to facilitate sustained yield on our forest lands.

DISCUSSION

R. C. FRAUNBERGER (Philco Corp.): What price do you think cedar cut to length stock like your sample will command?

F. C. SIMMONS (NE Forest Expt. Station): It is true that clear cut-to-length stock has not had a favorable market in recent years. When the automobile body manufacturers stopped using this class of material a lot of manufacturers were competing with each other for the remaining markets and trying to dig up new ones. The purchaser could practically dictate his own price. This situation is changing now. As good grade hardwood lumber becomes scarcer and more high priced, users such as furniture companies are casting around for other sources of supply for the cuttings they need. Clear cut stock interests them a great deal. Such clear cuttings can be made from low grade lumber at the sawmill, eliminating the cost of transporting defect across the country. It can also be made from second growth too small to be economically converted on a standard sawmill. The Jamestown people are particularly interested in this cut stock, and several of them are getting set up to receive it, green, in steel strapped bundles with the stickers inserted between each course, and the ends coated. The president of one of these companies, who is buying upwards of 10,000 feet a day of such material, told me a few weeks ago that he was glad to pay FAS prices for it.

F. J. BUSS (Perkins Glue Co.): Why not price the same as FAS on the basis of clear cuttings?

PROF. HOSMER: If these cuttings will meet the requirements for "minimum size of cuttings" as in FAS and since they are clear cuttings, it would seem logical that a price could be worked out on this basis.

A. B. RECKNAGEL (St. Regis Paper Co.): I agree that integrated operations for pulpwood and lumber are sorely needed to get complete utilization. This has not been achieved because the erection of pulp and paper mills is excessively costly and the shipment of raw material to existing mills is restricted by high costs of transportation. Some progress is being made but it falls far short of the desirable goal.

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Core Gluing Equipment

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BASIC EQUIPMENT FOR PRESSING

BROADLY SPEAKING there are two general types of such equipment - carrier clamps and mechanical presses. In the former I refer specifically to the overhead carrier clamps with which we are all familiar and which I imagine all of us who are engaged in the manufacture of wood work have used at one time or another. In the latter I have in mind the newer developments in core gluing equipment in the form of mechanical presses which fall into two groups depending upon the heating medium - steam heated platen type or electronic type. Each of these includes both the batch and continuous types.

In consideration of any core gluing equipment, the volume of production required is an important factor in determining the type to purchase. Also the type of product is a factor which must be considered, that is, whether the machine is to be used simply for core work or the fabrication of solid lumber panels such as mahogany, maple, cherry, and the like. This discussion, however, is confined principally to core gluing, so with this in mind our more important consideration is volume of production in relation to the amount of money we can spend, available floor space, and the quality of the joint which we must have.

Basically any of the present methods of fabricating cores currently in use will produce a good core provided the stock is properly prepared, the right kind of glue is used the way it should be used and the equipment is operated as it should be operated. I have seen perfectly satisfactory equipment condemned as "no good" simply because those connected with its operation violated one or more fundamental principles somewhere along the line, and because the machine was not able to compensate for those errors it received the entire blame for producing cores that were not satisfactory. Maybe it's a good thing that some of our equipment cannot talk back to us though as I imagine a good many of us would get a rude awakening and a liberal education if some of it could.

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There are limitations to what any piece of equipment will do, and I am not going into too much detail as to what some of these limitations are because in the first place I don't know too much about some of them, and in the second place there are no doubt representatives of manufacturers of different kinds of core gluing equipment present, and I do not want to start any competitive arguments, particularly where I might find myself in the middle. Therefore, let us confine outselves briefly to a general discussion of the different types of equipment available and in use at the present time.

CARRIER CLAMP

First, we have the carrier clamps - wheel clamps, or as most of us know them - the Taylor clamp. I imagine this machine was probably the first to permit volume manufacture of core stock, and all of us are familiar with them and their method of operation. One finds about as many methods of operating such a clamp as there are people to do it. It will accommodate both animal and resin glues. The operator himself can apply the glue to the component parts of the panels or this can be done by helpers and fed to him on conveyors. It is, of course, a type of batch press where only one panel is glued at a time. We find some of these clamps hooded so that the panels pass through heat to facilitate drying and increase production. The presence of heat is a necessity if resin glues are used. The successful operation of these clamps both from a standpoint of quality as well as quantity depends to a large extent on the human element. The individual clamps are usually manually tightened, and if the operators do not get them tight enough insufficient pressure is applied and the quality of the glue joint suffers. As the day wears on the men begin to tire and not only does quality suffer but likewise quantity. Side pressure, of course, is extremely important and where it is manually applied it is, to say the least, anything but positive and oftentimes not enough. I venture to say that if everyone knew how little pressure he was getting on some of his core joints in this type of equipment he would be appalled and lose no time in doing something about it. The use of resin glues likewise increases the importance of pressure because we know that proper pressure is more critical with resin glues than with animal glues. There is one thing about this type of equipment that has always impressed me and

that is the hammering of the cores after the maior portion of the pressure has been applied so that the individual strips will be flushed up and the joints properly seated one against the other. This one operation certainly covers up a multitude of sins in our sawing operations. I am quite sure that when a lot of us first started using other types of equipment it wasn't long before we were scurrying back into our rough mill to find out what we were doing wrong back there which was keeping our brand new core machine from making good cores or we were calling up the manufacturer and telling him the machine wasn't any good.

HEATED PLATEN PRESSES

I believe that the first departure from the preceeding type of core equipment occurred some years ago when the heated platen type of machine was developed. As I recall, the first such machine which I saw was in North Carolina about 1938. Progress in this type of equipment has moved forward at a rapid rate since that time, and we now have several satisfactory machines of the mechanical press type. Perhaps this method of core manufacture is capable of the highest production rate of any on the market at the present time. Certainly, if not the highest, it ranks at the top with others of equally high capacity. These machines are largely automatic and are capable of high volume production with a resultant low cost. They can produce cores in a continuous strip or a single width at the option of the operator. Further, these machines can produce cores in multiple length which are later cut off to net size.

Let us briefly go through the various phases of core manufacture on this type of equipment.

PROCESSING IN STEAM HEATED TYPE

After the core strips have been properly machined as to length and width, they are run over a glue spreader which deposits the proper amount of glue on the edge. The degree of machanization of this operation depends largely on how far one wants to go from one where the press operator passes a group of boards over a glue roller to the one where the entire pre-gluing handling setup is largely automatic. In the latter case the core strips can be hopper fed onto a power driven conveyor which, by means of vertical-axis feeding rolls passes the core strips, on edge, over a glue spreader and on over knife edge rollers, which do not disturb the glue spread, to the operator at the infeed end of the core press. The operator picks the individual boards up and places them down flat, edge to edge on a chute or conveyorized table which feeds the press itself. At this point it is well to state that the core strips have already been cut to the proper length or the proper multiple of shorter lengths, if one is going to subsequently make two or three and so on. Further, if single cores are to be made the cores come to the operator matched to width where the glue has been omitted from the outside piece. If the core is to be made into one continuous strip, glue, of course, is applied to the edge of every board.

The glue press itself consists of two steam heated platens with one stationary and the other usually hydraulically operated. These platens are usually about eight feet wide and run anywhere from twelve to twenty feet in length. Going back to our boards, which we left a few minutes ago on a conveyor or chute headed for the press, we find them traveling abutted edge to edge toward the opening between the two heated platens, where they either pass through heavy rollers or between caterpillar type feed chains. These rollers or feed chains, as the case may be, carry the stock into the press where there is sufficient down pressure exerted by the hydraulically operated platen to flatten out the individual boards and place them in the same plane and at the same time impede their progress through the press to the point where sufficient edge pressure is developed by the feeding mechanism to provide intimate contact between the edge of each board. Other methods of developing this edge pressure are heavy rollers at each end of the press where those on the infeed end run at a different speed than those on the outfeed end, thereby causing a pressing action inside the press. As the cores or core ribbon, as the case may be, proceeds between the platens at a speed of from 3 to 10 feet a minute in the presence of heat and pressure the glue in the joints is rapidly cured with the outside, of course, curing first as the heat moves from the outside to the center of the joint. The curing of the glue is associated with a loss as well as dispersion into the core of the water in the glue. On the outfeed end of the press we find a traveling rip saw which automatically cuts the core ribbon into the desired width provided a continuous strip is being glued and not matched single cores. The core stock at this point is ready for stacking or sticking and further curing before subsequent machining operations.

You will note that I have just said "further curing." No doubt there are those who will take issue with me that further curing is necessary. However, I feel that it is because of two reasons. First, the glue in the center of the joint is not always fully set and the stresses set up by handling and machining are likely to break the joint loose before the glue has time to fully set. The

length of time required here, of course, is not very long and is more a matter of minutes that it is hours, particularly because a considerable amount of heat remains in the panel which naturally hastens the curing of the glue. My second reason for further curing, though, is by far the most important which is to eliminate or minimize the danger of sunken glue joints associated with planing too soon after core fabrication. The length of time that the core is in the press - anywhere from two to four minutes - is not sufficient exposure to the drying action of the heat to properly disperse or distribute the relatively high concentration of moisture around the glue line to the point where we eliminate the potential danger of sunken glue joints. Not only do we know that from experience but various tests made by industry as well as the Forest Products Laboratory seem to substantiate this fact. There are some circumstances, of course, where this danger diminishes, but in this day and time of the high gloss finishes that we are crazy enough to put on our furniture (in dark colors at that) close consideration must be given proper curing before machining.

Use of the RF Type

The second broad kind of core equipment which comes under the press type is that utilizing the principle of electronic or high frequency gluing which we commonly refer to today as RF gluing. This method is of more recent development than the two preceding types. As a group I would say that the productive capacity of this falls somewhere between the clamp method and the hot press method. Furthermore, I would say we know less about the ultimate possibilities of high frequency gluing than we do about hot pressing and air curing.

In connection with RF gluing we find both the continuous and the batch press, with the latter type probably more in use than the former. The kind of auxiliary equipment such as rip saws, jointers, glue spreaders, etc., has a direct bearing on the amount of production available out of a given electronic press.

RF equipment necessitates two main component parts - a mechanical press to develop the required pressure on the glue joints and a high frequency unit. No additional time will be used to discuss types of presses other than to say that one noteworthy development is a batch press which can be operated at a fair production rate with one person. The operator feeds the press and since the line of motion of the outfeed side is at 90° with the line of motion of the infeed side the same operator removes the completed core from the machine.

The size of the RF unit, of course, is determined by the amount of production required, the size of the cores to be made, and the kind of wood to be glued, that is, softwoods or hardwoods. There are still many factors involved in RF heating that a great many of the users do not fully understand, and I must be included in this category. Basically, though, electronic gluing consists of converting alternating current into direct current which is in turn stepped up in voltage then converted back to alternating current at extremely high frequencies of usually from 5 to 6.8 megocycles. By means of electrodes, one grounded and one "hot", set one over the other with the stock to be glued in between, this high voltage passes through the core. Since the wet glue is a better conductor than the relatively dry wood it heats up rapidly and therefore cures in a matter of seconds. The phenomenon of this rapid heating is simply a case of the molecules which make up the glue being violently disturbed by the high frequency electrical waves to the point where they do a lot of running around and bumping into one another causing a lot of friction among themselves. And - as in any case of friction, whether it is between humans or molecules - heat is developed and the glue sets.

RF edge gluing is perhaps more sensitive to improper preparation of stock and other gluing conditions than other methods. Noteworthy of mention are:

1. Edges must be square and flat in relation to each other. Failure to accomplish this will result in uneven heating, excessive time for curing or arcing, any one of which can cause inferior joints.

2. The thickness of each individual piece must be uniform. Otherwise the unit will not function properly. Some people advocate a thickness variation of not more than 1/16 inch, but I have seen instances where a variation of less than 1/16 inch has caused trouble.

3. Moisture content must be controlled between about 6 and 10 percent. If the wood is too dry the glue strikes into the wood and impairs the joint. If the moisture content of the wood is too high, our experience has indicated that not only is the time factor increased due to the increase in conductivity of the wetter wood but there is a definite danger of arcing and uneven heating with a resultant poor joint if any at all is obtained.

4. The proper glue itself must be used - one which is particularly adaptable to RF gluing. Most glue companies today are fully aware of the importance of electronic gluing in the woodworking industry and are in a good position to give valuable

advice as well as service on gluing problems attendant to the use of high frequency equipment.

5. Proper glue spread must be applied and maintained, otherwise some of the foregoing troubles will result. Depending on the density of the wood being worked, the glue spread should range from 30 to 45 pounds per thousand feet of single glue line. Double spreading is not recommended. There are those who sometimes feel that a heavier glue spread will compensate for poorly prepared joints when actually such a practice usually does more harm than good. Since the advent of synthetic resin glues I have felt that a heavy glue spread was just as bad as one which was too light for any type of gluing, and this principle holds true in RF gluing equally except that there are just a few more problems added which are not present in other gluing methods.

No discussion of core gluing equipment is complete without mention of the important part which the glue manufacturer has played in the development of suitable glues for use on this equipment. I am sure that had it not been for the research and development carried on by the glue industry from which resulted the various resin glues we would not have witnessed the improved gluing techniques which are available to us today.

Fundamentals of Broad Application

This paper has dealt briefly with three methods in current use for the manufacture of lumber cores - carrier clamps, hot press and RF gluing. Regardless of the method used there are certain fundamental principles which must be followed in order to obtain satisfactory results. While some of these factors are more important in one type of gluing than in another they apply basically and generally to all.

1. The stack to be glued must be relatively flat.

2. The edges must be square and straight.

3. The mating surfaces themselves must be smooth. Considerable discussion is often heard about the relative merits of a sawn joint versus a jointed joint. Either will give good results provided the equipment is in good condition and the cutting tools sharp. Oftentimes, though, with sawn joints we think we have a good gluing surface when we really have not because, instead of cutting the fibers clean, we have in effect knocked a lot of them down. While a subsequent examination of the shear area through the glue line of such a joint gives what appears to be 100 percent wood failure, what we actually have is 100 percent ruptured fiber failure. The plane of this failure is immediately adjacent to the glue line itself, and the well known jagged break following the grain of the wood away from the glue line designating a good glue joint is notable for its absence.

4. Moisture content of the lumber must be between 6 and 10 percent or at least compatible with the type of glue and equipment being used.

5. Sufficient down pressure must be available to properly flatten out the individual boards in relation to each other.

6. Edge pressure must be adequate, usually around 200 psi. to force the adjacent edges into intimate contact with each other. I believe that I can say without fear of contradiction that in my entire experience in any type of wood gluing that the largest single factor causing poor glue joints is lack of adequate pressure. This comes from a variety of causes ranging from poor preparation of the gluing surface itself to inadequate mechanical pressure on an otherwise good joint.

7. The proper selection of the adhesive itself. In carrier clamps we find a variety of glues being used, but in steam heated platen and electronic presses we use resins.

8. Glue spread must be maintained at not only the correct amount but it must be uniform. This is particularly true in the case of resins where it should be from 30 to 45 pounds per thousand feet of single glue line.

9. Sufficient curing time for the glue must be allowed while the joint is still under pressure. This, of course, depends on the equipment being used as well as the type of glue. The times here will naturally vary widely from an hour or so in the case of carrier clamps to a matter of seconds when RF is used.

10. After removal of pressure a further curing period should be allowed consistent with the requirements and performance of the end product.

DISCUSSION

R. LENOX (William Furniture Corp.): What effect do drying schedules have on sunken joints?

R. F. WILDER (The Mengel Co.): I knew someone was going to ask that question before I came here, so I came prepared. Last month in Oshkosh, Wisconsin I had the pleasure of hearing a paper presented by Mr. Selbo of the Forest Products Laboratory on the effectiveness of different conditioning schedules in reducing sunken joints in edge-glued lumber panels. I think the best way to answer your question is to give you his recommendations. These panels Selbo mentioned were glued with both urea resin and animal glue, and finished to a high gloss.

The panels were strictly lumber panels, that is there were no veneer faces on them. The required conditioning period decreased with an increase in temperature and humidity so that the same obliteration of the joints was obtained with the following treatments:

(1) seven days at 80° F. and 30 percent relative humidity,

(2) four days at 120° F. and 35 percent relative humidity,

(3) 24 hours at 160° F. and 44 percent relative humidity,

(4) 16 hours at 200° F. and 55 percent relative humidity.

He goes on to say that for edge-glued furniture panels that are subsequently covered with cross bands from 1/16 inch to 1/20 inch in thickness and face veneers usually 1/28 inch thick, it is expected that the conditioning time shown above can be shortened at the different temperatures by about half.

C. LATIMER (Nickey Bros.): On veneered panels glued-up with high frequency is this conditioning period necessary?

R. F. WILDER (The Mengel Co.): Yes. As a matter of fact, the test Mr. Selbo made was on both high frequency and steam platen presses. He indicates that he observed no differences in the degree of sunken joints regardless of the type of press used. I should add, based on our experience, and in our particular operation we used both the Taylor clamp and the bench press high frequency for the type of furniture we make with the light finishes. We age our panels from 24 to 48 hours, and we do not encounter many sunken joints, but if we go to mahogany faced panels and a cordovan finish with an extremely high sheen, then 24 hours is not sufficient.

MR. WEBER: Do you use both carbide and high speed saws?

R. F. WILDER (The Mengel Co.): Yes, we use both.

MR. WEBER: Did you notice any difference in these two types?

R. F. WILDER (The Mengel Co.) No, at least we didn't find any.

R. CARTER (N. C. State College): Are there any other factors besides glue lines that can cause sunken joints?

R. F. WILDER (The Mengel Co.): I think we often see a condition which looks like a sunken joint, but actually it isn't. When we use resin glue what we have in effect when it sets is a rigid, immobile, glue line, and immediately adjacent to that glue line we have impregnated wood. The set glue line is not going to move, or perhaps I had better say, it isn't going to respond to varying moisture conditions, but on either side of it the wood itself can expand easily and become infinitesimally thicker than it was before being subjected to a high moisture content. The result of course is what the layman would call a sunken joint when actually the joint hasn't sunk at all but the all around it has expanded.

C. E. LEHMAN (Peter Cooper Corp.): If seven days is required to properly condition cores made up with urea resins, how long a period is needed for animal glues?

R. F. WILDER (The Mengel Co.): Mr. Selbo included both resin and animal adhesives in his study, and whereas he found that resin glues did not require quite as long a period of curing, I gather from his paper that he recommends the same curing periods of time regardless which type of adhesives is used. He stated that sunken joints were still faintly visible in both yellow poplar and white oak panels glued with animal glue when the surfacing was done after seven days of conditioning at 80° F. He asserted further that urea resin glue joints were consistently sunken after three days of conditioning at room temperatures and sometimes faintly visible after seven days.

K. REDMAN (Redman Engrg. Service): Did Mr. Selbo state the moisture content of the core stock at the time it was glued-up?

R. F. WILDER (The Mengel Co.): Yes, 6 percent.

R. CARTER (N. C. State College): How did Mr. Selbo measure the sunken joints that did exist in the test panels?

R. F. WILDER (The Mengel Co.): He used a 750-watt bulb through a projector shining on the surface of the panels after they has been finished.

C. E. LEHMAN (Peter Cooper Corp.) Would heartwood and sapwood boards glued together cause a condition of sunken joints?

R. F. WILDER (The Mengel Co.): Yes, but I think in such a case however, one gets a condition that the TV. people call core shrinkage. Under the category of your question is also the relationship of quartersawn to flat or bastard sawn boards adjacent to one another, or with a variation in moisture content among different boards in the same core. When such a panel is made and in the cabinet of a TV set and in the customers home, he looks at it, sees a washboard effect across it, and then says the TV set is no good. What he has here, however, is not sunken joints, but sunken boards.

Quality Control in Gluing on an Industry Wide Basis

CLARENCE W. DIETTERICH, Managing Director, Southern Plywood Manufacturers' Association, Atlanta, Georgia and JOHN L. BUTLER, Wood Technologist, Darlington Veneer Company, Darlington, S. Carolina

INTRODUCTION

AN ACTIVE QUALITY CONTROL program is fast becoming a basic requirement for successful participation in the hardwood plywood manufacturing field. It might be said that World War II played a most important role in the initiation of this present trend toward a quality-controlled product. Government contracts required exacting conformance to very stringent specifications, conformance obtainable only by exerting a high degree of control over the manufacturing process. After the war there was a general let down in quality due in great part to the tremendous demand for plywood products and the attendant willingness of the consumer to accept any and all material offered. However, many producers experienced in plywood manufacture under government contracts had come to realize the economies that might be achieved through exercising quality control in their normal manufacturing. The misconception that quality control applied only to such carriage-trade products as aircraft plywood and similar specialty plywoods was fast being discarded. Rising material and labor costs served as a further impetus to control manufacturing cost through assuring the production of a uniform product. A product not only uniform from the standpoint of the grade of face and back veneers, but uniform in size, thickness and in glue-line performance. In recent months continual requests for information concerning the Hardwood Plywood Commercial Standard CS35-49, from present as well as potential consumers of hardwood plywood, serves to indicate the ever increasing demand for materials of a definite and dependable quality level.

INITIATION OF A QUALITY CONTROL PROGRAM

In recognition of this trend, the commercial plywood industry of the South, in the Spring of 1948, embarked on its most recent developmental program when it inaugurated a long-range industry quality control program. The establishment of this program, which was patterned after that so successfully developed by and maintained in the Douglas fir plywood industry, was a first and history-making event in the hardwood plywood industry.

Presented at meeting of Virginia-Carolinas Section, Forest Products Research Society, Clemson, South Carolina, October 26, 1951.

OBJECTIVES OF QUALITY CONTROL PROGRAM

Initial objectives in this program of quality control were: (1) establish and maintain a well equipped plywood testing laboratory for use in maintaining quality of bond throughout our industry; (2) establish and maintain a qualified inspection service for the two-fold purpose of helping the mills maintain quality of panel grade and other production operations, and to furnish a competent arbiter for disputes that might arise between a plywood manufacturer and his customer; (3) establish and maintain an appropriate grade-trade marking program for our industry's products. It is with the first objective of this program that we will be primarily concerned for the purpose of this paper.

ESTABLISHMENT OF A TESTING LABORATORY

The plywood testing laboratory was established in June 1948 as an activity of the Southern Plywood Manufacturers Association, the trade association of the southern commercial plywood industry. Since that time the association laboratory has tested an average of over 200 panels per month for glue bond integrity. These panels, which in total have come from 40 southern mills, have been manufactured and tested in accordance with such plywood specifications as MIL-P-6070, Plywood and Veneer, Aircraft Flat Panel; JAN-P-66 and MIL-P-66A, Plywood, Flat Panel, JAN-P-139, Plywood Container Grade and Hardwood Plywood Commercial Standards CS35-47 and CS35-49. I am happy to report to you that the total net results of these tests indicate glue bonds of high quality.

These high-quality bonds are illustrated in data obtained from our records of Type II, CS35-49 glue-bond tests. Plywood containing this type of bond must withstand two cycles of soaking in water at room temperature for four hours followed by drying at room temperature for 20 hours. Since the establishment of the association laboratory, we have followed the procedure of applying an additional eight cycles of the cold soak and dry test to all Type II bond CS35-49 test specimens which pass the two cycle test. Our records show that these test specimens pass an average of nine cycles out of the total test of ten cycles. On several occasions we have continued these tests for additional cycles and found that a majority of the test specimens

from each group passed 20, 30, 40 and even 50 cycles of the cold soak and dry test.

RATING OF TEST RESULTS

In order to provide test information of the greatest possible value to the industry it is the policy of the association to report tests results in Type II bonds on a percent rating basis as follows: (1) each test panel is cut into three test specimens; (2) each test specimen is given a base rating of 100. This rating is given before valuation; (3) the test specimen base rating multiplied by the number of specimens tested equals the total base rating of the test; (4) a rating of 50 is given for each cycle each test specimen passes in two-cycle testing and a rating of ten for each cycle passed in ten-cycle testing; (5) the total rating of cycles passed divided by the total base rating equals the percent passing the test; (6) specimen failures caused by defects permitted in the grade or by tape, receive a "no-failure" rating of 100; (7) the following type failures are counted against the specimen:

Poor glue transfer, dried glue line
Poor glue transfer, cause undetermined
Poor glue transfer, has appearance of wet stock
Poor glue transfer, rough inner plies
Glue failure, cause undetermined.

UNIFORMITY OF SAMPLE PANEL DATA

At the present time mills are selecting test panels either from the press or the warehouse stock. Under such a system of sampling, data accompanying the test panels frequently fails to describe completely the conditions under which the panels were glued. We feel that with information concerning the name of the glue, the glue mix, rate of glue spread, total lay up and assembly time, location in the press and etc. more adequate explanations of test sample behaviors might be forthcoming. To encourage more accurate reporting printed data forms are supplied by the association along with an illustrated explanation of their proper use. This explanation sheet is also recirculated periodically as a reminder.

EXPOSURE FENCE FOR EXTERIOR PANELS

In order to help gauge the industry's ability to manufacture waterproof type panels, the association in March 1949 established and now maintains a plywood exposure fence in an open field near Atlanta, Georgia on which are now attached about two thousand unprotected test pieces of plywood each 3 inches by 11 inches in size. These test pieces were obtained from run-of-the-mill test panels, received in the association laboratory and tested for a waterproof type glue bond. A recent examination of this plywood exposure fence indicates that these panels which passed the accelerated laboratory test satisfactorily are also satisfactorily withstanding the ravages of year-around weathering.

IMPROVEMENTS IN GLUING CONTROL TECHNIQUES

In line with its program of continuing progress it is the desire of the industry to take full advantage of new quality control techniques. It is currently contemplating the use of improved statistical methods of sampling and reporting data. An improved method of random sampling will be initiated by the association in the near future, a method paralleling that now used by the Douglas Fir industry. Samples will be selected by chance from the press operation in sets of four by means of small chips numbered from one to twenty five to correspond with the number of plate openings in the hot press, or caul boards in the cold press. Mills will be encouraged to submit a minimum of eight panels per week. Consideration is being given to the possibility of plotting test results of these samples on a p chart, (fraction defective) the mean and control limits of which will initially be determined from test data accumulated on the particular mill during the past three years. Individual charts will be kept for each mill and copies will be included with the test report returned to the mill.

A second chart is also being contemplated for monthly publication. This too will be a p chart but will represent all mills submitting material for testing during the reporting period. Mills will be identified by code letters only with each mill knowing only its own code designation. This chart will serve to inform the mill of its comparative position in the industry on the basis of glue line performance. These methods will be applied initially to the Type II bond only, but will eventually be applied to Type I bonds as well with the exception that X and R charts will be substituted for the p charts for the individual mills.

INSPECTION SERVICE BRINGS TECHNICAL HELP TO THE MILLS

In August 1950 an inspection service was established as an activity of the Southern Plywood Manufacturers Association. During the past thirteen months the association inspection service has given a great deal of practical and valuable assistance in various production problems to over 20 southern plywood mills. In addition, the Association has completed a rather comprehensive grade survey throughout the industry.

In closing I would like to say the third indicated objective of the long range quality program of the southern plywood industry, that of a grade-trade marking program, is still in the developmental stage. I have reason to believe, however, that before another year has passed this program will have been inaugurated.

New Trends in Panel Gluing

JOHN W. MAXWELL, The Borden Company, Bainbridge, New York

INTRODUCTION

WHAT'S NEW in panel gluing? To mention a few factors, we have new glues, new procedures of handling glue, new means of educating personnel and new practices in conducting research. These have all contributed toward a trend in panel gluing. They have led us toward complete modernization of equipment, new arrangements for factory layout of equipment to include conveyors and other time-saving devices, new equipment having means for refrigeration of glues, high-frequency generators, and many other mechanical improvements.

Why have these new developments come about? Because of the age-old driving force of competition. The need for manufacturing products at a lower cost with equal or superior quality. We all know that if we intend to stay in business we must be able to keep our products competitive with those made from other raw materials.

What are the new trends? Why have they come into use? How can they benefit you in your effort to produce a superior product more economically? In the discussion that follows we will be concerned with what, why, and how you can improve the quality of your product through new trends in gluing.

TRENDS IN GLUES

Low-Solids Urea Formaldehyde Resin

This product enjoys wide usage due to its greater stability in storage than the high-solids product and its ease in pumping, a factor of great importance when bulk installations are considered. Its use parallels that of higher-solids resin. Performance-wise it compares directly with higher-solids glues when both are used with wheat flour on comparable flour-to-resin solids ratios.

Catalysts

Catalyst improvement plays a major role in adhesive applications of today. The use of more reactive catalyst chemicals in lesser quantity has been a significant trend, especially for flat panel hot and cold pressing operations. Purchase of chemicals directly from the chemical wholesalers has enabled a substantial saving on the part of large plywood and furniture plants. Adhesive suppliers will supply the needed information for use of these low cost catalysts.

Glue manufacturers have been conscious of the cost of catalyst systems and have tried to reduce them. There has been a reason for a trend in catalyst cost reduction. When resins were first introduced, a much higher degree of care in weighing and mixing ingredients was required. For these reasons catalysts were "bulked" so that larger amounts, easier to weigh, would be used. And, of course, by combining catalyst, retarder and filler into one component, mixing was simplified. Now - when means for accurate weighing are available, catalysts which contain little or no filler can be utilized and the filler purchased directly in the form of wheat, walnut shell, or wood flour.

Today glue manufacturers can recommend the best catalyst for the application problems in mind. They employ a technical staff well versed in the fundamentals of resin manufacturing, wood technology, etc. By purchasing the catalyst from the glue manufacturer, one obtains the advantage of a tried and tested formulation.

Tapeless Splicing

Specialty glues for use in tapeless splicing operations have been improved . The trend is toward pre-spreading the jointed veneers by spray gun, then allowing a slight drying prior to passing them through a splicer. This pre-drying minimizes the fouling of the heater bar. Use of silicone-treated papers to polish the heater bar also reduces fouling if drying is not completely uniform.

Core Stock Edge Glues

Core gluing machines now operate at peak speed by using very reactive glues that are kept at a temperature below 60° F. to retard their action until the glue is on the wood and the wood is passed between heated plates. Production rate from these machines is extremely high. Floor space is conserved. Another parallel operation is performed with radio frequency heat. These installations are a definite step forward in gluing practice.

Presented at meeting of Virginia-Carolinas Section, Forest Products Research Society, Clemson, South Carolina, October 26, 1951.

Craze-resistant Glues

Use of craze-resistant glues for panel subassembly is considered excellent practice. Craze-resistant glues act as gap fillers to bridge the space between irregular surfaces. They give better results on dense wood, Formica, etc. A variety of catalysts are available to allow selection for speed of mix.

Durable Room-and-Low Temperature Curing Glues

Other glues of great importance but not widely used for panel manufacture are the completely durable resorcinol and phenol-resorcinol formulations. Also the acid curing phenols fall in this general category but cannot be classed as completely durable, from their performance records thus far. These glues are used primarily for laminating and assembly gluing and play a major role in marine gluing or other exposed applications where maximum durability is imperative. They have been found to produce the best glue bond when treated woods must be glued.

Fortified-Urea Glues

Melamine, resorcinol and phenol derivatives have been successfully used to fortify urea-formaldehyde glues. The procedure of curing these glues determines the ultimate durability. Hot pressing produces the superior panel.

Phenol Glues

This adhesive is still the preferred glue for the manufacture of exterior grade or marine grade plywood. It must be used in a hot press operation in order to polymerize the resin.

Dustless Powdered Adhesives and Catalysts

Dustless powdered adhesives and catalysts are also definitely improved products which are less hazardous from the health standpoint. They allow full use of purchased material and reduce the resin build-up on the sides of mixers. Yet to come in this approach are odorless or pleasant smelling glues.

Glues for Wood-Waste Applications

Development of new glues and equipment for wood waste applications has enabled a more complete use of wood shavings and waste veneers with the resultant production of an excellent core and panel material. This trend in waste wood utilization would require a paper in itself. The problem is in the development stage except for a few plants where chip core or door panels are being made on a production basis.

Specifications and Standards

The trend is toward production of plywood in compliance with Commercial Standards. These standards were set up by the industry itself to control the quality of the product it manufactured. It acts as a guide for judging the quality of plywood.

Government specifications likewise have set up a measure of quality that a manufacturer must meet in order for his product to be accepted.

Test procedures set up in the above mentioned standards and specifications are quite complete. One can select a standard or specification according to the application in question and feel confident that if it passes the test for a certain quality panel then the plywood will meet his requirement.

MANUFACTURING PROCEDURES

Bulk Shipment

This means of transporting liquid resin glues to the consumer has been promoted with some difficulty due to the risk, capital expenditure, and the necessity for development of suitable equipment and know-how. The practice today is well proven and a definite trend toward wider use of bulk practice has been established. The saving to consumer and manufacturer is very obvious when one considers the steps involved in the two possible methods of shipping liquid resin glue:

Drum shipment

1. Filling.
2. Weighing and marking.
3. Loading into box cars.
4. Unloading drums and warehousing.
5. Moving to the glue mixer.
6. Drawing resin.
7. Returning drum to sender.
8. Cleaning and painting drums.

Bulk handling

1. Filling tank car or truck.
2. Unloading into bulk storage.
3. Pumping resin into mixer.
4. Return of tank car or truck for refill.

Figure 1 shows a typical bulk storage layout.

Adhesive companies offer consulting assistance to consumers interested in this type of installation.

Low Cost Glue

What other supplier of goods can say his prices are equal to or lower than pre-war prices? This proud accomplishment has resulted from new methods of producing adhesives. Use of larger reactors, new chemical formulations and more efficient methods for handling raw materials and finished products, have contributed toward keeping the cost down.

A West Coast firm that made balsa life rafts during World War II looked up their records

and found that the present price of liquid resin glue was within 1/2 cent of the former purchase price. They reported that, within the same period, labor costs had doubled, cotton prices were three to four times higher, and balsa several times higher.

Education

Adhesive companies, forestry colleges and universities, The Forest Products Laboratory, private research companies, and Forest Products Research Society have contributed a great deal toward the educational trend in good gluing. The major part of this educational promotion has been directed toward the managerial level of industry. What about the education of the man who is right on the gluing job? Have we made an effort to improve his knowledge of good gluing practice? His ability to foresee and correct poor gluing practice would be an invaluable aid toward improving the quality of your production. A program of eduction in good gluing practice would be as important as your safety program.

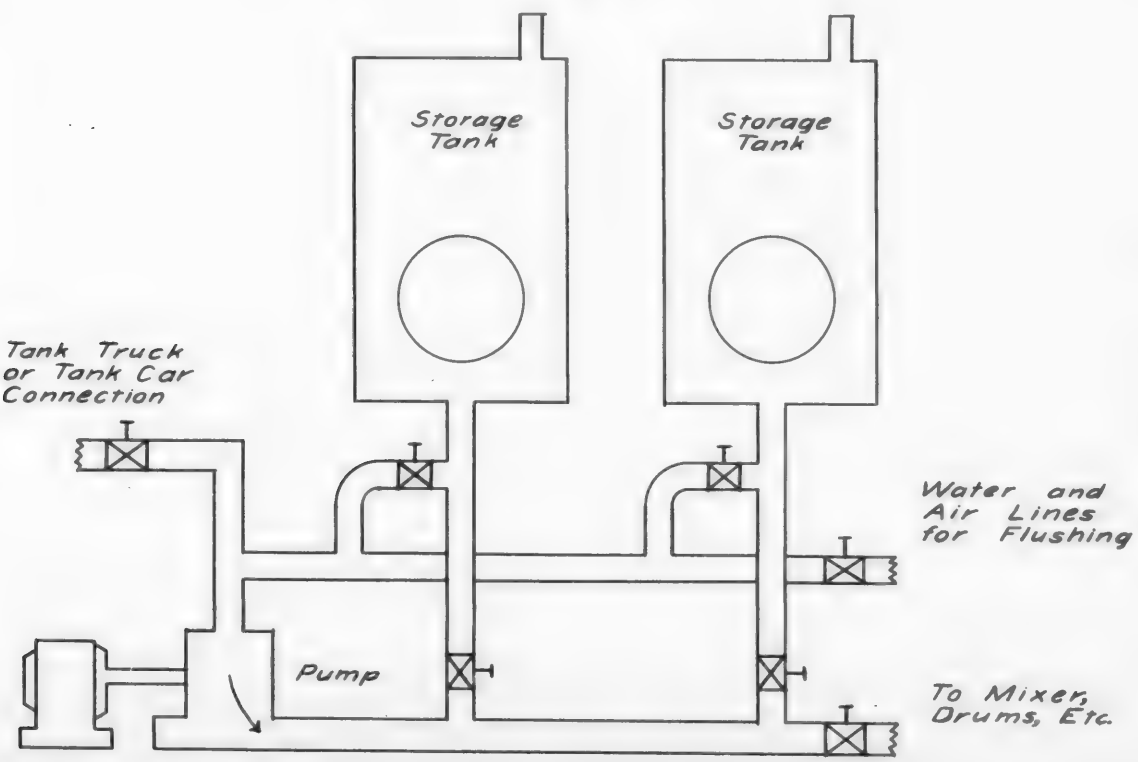
Research

It is the trend for research to lean toward a closer association with production problems through technical service and application-engineering groups. A careful analysis of production requirements aids research in its effort to improve adhesives to meet production problems. The development of a new glue or catalyst system requires months of research before it can be put on the market. It must be examined in comparison with previously used products. A few of the laboratory tests that it must undergo are as follows: stability, rate of cure at various temperatures, viscosity, strength of bond, water-resistance, caking tendency (if powder), ability to reproduce within specification, film pH, etc.

When a new product meets or betters previous products, it is first field tested by the technical service group, followed by the writing up of instructions, sales education, sales promotion, and finally customer acceptance. Once in production, a new glue requires constant vigilance on the part of the sales service staff for confirmation of laboratory and technical service findings to be sure the new product is actually an improvement over prior products. Meanwhile, research is using its knowledge of prior products combined with the knowledge gained from the new product performance vs. more recent laboratory discoveries to further improve the product. It is a never-ending cycle.

The development of new glues, new machines, new products, new needs will lead us all from one improvement to another. If we, the consumer and producer, are on our toes and benefit from experience by working together cooperatively, we will all benefit in the age-old battle of competition - the very foundation of our American economy.

Fig. 1



JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Structural Lumber, Past-Present-Future

T. K. MAY, Director of Technical Service, West Coast Lumbermen's Association, Portland, Oregon

EARLIEST GRADING RULES

RELIANCE on grading rules, as a means of segregating lumber, predates any concept of a structural grade by over a century. One early reference to a grading rule is to that formalized by Swan Alverdson in Sweden in 1764. Therein he defined four classifications of "best", "good", "common" and "cull." In this country lumber was beginning to be segregated by grades in Maine about 1816. In 1833 the State of Maine passed a law for the inspection of lumber in Penobscot County. This law related to boards and was based on clearness and thickness. No. 1 was required to be clear and not less than one inch thick. No. 2 was required to be not less than three-fourths of an inch thick and suitable for covering buildings. No. 4 was boards excluded from other grades, probably not much different from the No. 4 grade of today. Odd to us today is the fact that a state should concern itself with lumber grades, but apparently the business of lumber manufacture was of such concern to the economy of some states that Massachusetts, New Hampshire, Vermont and Rhode Island, as well as Maine, had statutes defining grades of lumber and provision for inspection.

During the late 1800's, lumber manufacturers' associations had begun to be formed in the pattern with which we are now familiar. The Wisconsin Valley Lumbermen's Association, the first to establish producers' grades, in 1895 began a system of inspection covering a large area. That same year the Mississippi Valley Lumbermen's Association started a similar service.

The earliest grading rules for Douglas-fir were published March 21, 1901, by the Pacific Coast Lumber Manufacturers' Association, a predecessor of the present West Coast Lumbermen's Association.

EARLY TESTS AND SPECIFICATIONS

As far back as there has been an interest in graded lumber, there has also been an interest in the strength of lumber. Of the earliest recorded strength tests are those reported in the Memoirs of the French Academy of Sciences in 1707 and 1708.

Best known of the early tests in this country are those made at the Watertown Arsenal by the Army Ordnance Department beginning in 1881. These tests were very comprehensive and well recorded. Along with these and numerous other tests that were being made on timber, tests were being conducted on bolts, nails and other methods of joining lumber to complement the increasing engineering knowledge about timber itself.

In 1884 test results were published on investigations made at the Watertown Arsenal on the withdrawal resistance of nails for five species of wood. A series of tests were made at Cornell University in 1894 to determine the relative holding power of cut and wire nails in Douglas-fir and redwood. Lateral resistance of nails was tested in 1897. Similarly, other fastening devices such as bolts (for which standards of size and form were developing about 1864), screws and lag screws were being tested for working strengths. Though the earliest organized tests on common fastening devices were made between 50 and 70 years ago, there are yet conditions of use for which values are assumed through want of reliable information.

One of the biggest users of lumber for structural purposes is the railroad group and fifty-two years ago (1899) railway engineers formed the American Railway Engineering Association. Fourteen committees were immediately appointed, one of which was assigned "Wood Bridges and Trestles." That committee still functions as No. 7 and is one of the oldest of the organization. Shortly after appointment, the committee adopted a standard specification for bridge and trestle timbers covering longleaf and shortleaf yellow pine and Douglas-fir. These specifications are rather simple and cover two grades. They read in part as follows:

"General requirements: Except as noted, all timbers shall be cut from sound trees, true and straight, and sawed standard size; shall be square edged, close grained, solid and out of wind; free from defects such as injurious ring shakes and crooked grain, unsound or loose knots,

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knots in groups, decay, large pitch pockets, or other defects that will materially impair strength.

No. 1 Railroad Grade:

Stringers: Longleaf pine shall show not less than 85 percent heart on the girth anywhere in the length of the piece; provided, however, that if the maximum amount of sap is shown on either narrow face of the stringer, the average depth of sap shall not exceed one-half inch. Douglas-fir shall show not less than 90 percent heart as measured above. Knots greater than 1-1/2 inches in diameter will not be permitted at any section within 4 inches of the edge of the piece"

A rather loose specification by today's standards. Apparently there was much dependence on first-hand knowledge between buyer and seller of what was needed.

The American Society for Testing Materials in 1905 organized "Committee O on Standard Specifications for the Grading of Structural Timber." Two years later the Society adopted the Committee's recommended standards.

Apparently the lumber manufacturers of the era were a trustworthy lot, for the only specification relative to timbers that shows in the 1901 Douglas-fir grading rules, previously mentioned, reads as follows:

"Fir Rough Timbers. Six by six and larger, shall not be more than one-quarter inch scant when green and shall be evenly manufactured from sound stock with not less than three square edges, and must be free from knots that will materially weaken the piece. Timbers 10 by 10 in size may have a 2-inch wane on one corner, or its equivalent on two or more corners, one-fourth the length of the piece. Other sizes may have proportionate defects. Seasoning checks and checks extending not over one-eighth of the length of the piece admissible."

In 1901, at the request of the Pacific Coast Lumber Manufacturers Association, The Bureau of Construction and Repair of the U. S. Navy made comparative bending, tensile, compression parallel, compression perpendicular, shear and abrasion tests on Douglas-fir and yellow pine. These tests were made at the Puget Sound Navy Yard to determine the suitability of Douglas-fir instead of the then specified "Georgia Yellow Pine" for construction and repair of Navy vessels, if found suitable the expense of importing Southern pine to the West Coast would be saved. A complete report of the tests was made to the Pacific Northwest Society of Engineers, at Seattle, July 5, 1902. By virtue of these tests, Douglas-fir was approved as equal to Yellow pine. However, no working stress values were determined or a relation established of grade to strength. These tests only served to determine the adequacy of an untried species for a particular use against a species which was deemed adequate by experience. Such were the tests generally made in those times, tests to determine the adequacy of the material for a particular use or for specific design data.

GENESIS OF MODERN GRADING RULES

In 1903, the U. S. Forest Service initiated the first planned tests to determine the strengths of structural timbers. Two progress reports were made and, in 1912, a bulletin was issued entitled "Tests of Structural Timbers." The species covered in this bulletin were: longleaf pine, Douglas-fir, shortleaf pine, western larch, loblolly pine, tamarack, redwood, Norway pine, red spruce, and white spruce.

This bulletin introduced the first proposal for grades of structural timbers. These tentative grading rules provided for only two grades. They recognized the principle of permitting larger knots in less critical areas but differentiated knot sizes into "small", those under 1-1/2 inches, and "large", those over 1-1/2 inches in diameter. The aggregate diameter was also limited in the middle half of the length. A minimum ring count and amount of summerwood, and a slope of grain of 1 in 20 were provided. Shakes or deep checks were not allowed. These constituted the Grade 1 requirements. Though ultimate strengths were carefully tabulated for each test, no working stresses were recommended, leaving it to the individual engineer to apply a factor of safety on average test values for suitable working stresses.

In the 1919 Grading Rules of the West Coast Lumbermens' Association appear the first table of recommended working stresses for Douglas-fir. Two grades were listed and apparently were patterned after those in the 1912 Forest Service Bulletin.

In 1923, the Forest Service published "Basic Grading Rules and Working Stresses for Structural Timbers." Herein were set forth four basic grading rules which were referred to as S1, S2, S3, and S4. Working stresses for each of the four grades were tabulated for thirty-eight species. This proposal was not favorably received by the lumber regions, probably because there was no way provided by which a weaker species could meet the competition of a stronger species by more restrictive grade requirements.

In 1934 the Forest Service published a "Guide to the Grading of Structural Timbers and the Determination of Working Stresses." This was expanded by a supplement in 1943 and 1948 a second supplement revised the basic working stresses. This publication, with its supplements, is the basis of stress grades today. Each lumber region is able to write a grading rule, commensurate with the characteristics of the species of the region and assign an appropriate working stress to the grade, a very flexible arrangement.

You are now up to date on the progress made with working stresses. To complete the picture, it is necessary to go back in time and bring the progress made with grading rules up to date.

As has been pointed out, grading rules by lumber regions were developing at the turn of the century. However, the qualities and sizes were not related between regions. This presented no difficulty to local customers, whose needs were supplied by one producing region, but with improved transportation, lumber moved into markets farther afield and producing regions became competitive. The conglomeration of grades, species and sizes in these areas could only result in confusion for the dealer in lumber and the ultimate consumer.

AMERICAN LUMBER STANDARDS

At the instigation of the U. S. Department of Commerce, a committee of lumber manufacturers, dealers and users was formed to develop basic standards for softwood lumber grades and sizes. As a result of the work of this committee American Lumber Standards was issued in 1924 by the Bureau of Standards, U. S. Department of Commerce. The American Lumber Standards Committee has been a continuing one, and the Standards are revised from time to time to keep them up to date. American Lumber Standards are the basis today for the grading rules of the softwood lumber producing regions. With the advent of methods of structural grading of lumber, such provisions were incorporated. Grade marking of lumber on an overall industry basis was begun in 1928. This too was instigated by the Department of Commerce.

The Standards of the American Society for Testing Materials and the Manual of the American Railway Engineering Association carried specifications for structural grades and tables of working stresses for many years. At one time this was considered desirable as recognition by these organizations of the principles and the grades of structural lumber lent weight to their general acceptance. However, in later years, these grade specifications lagged behind industry grade rules because industry is continuously and intimately aware of new developments as well as manufacturing conditions and takes prompt steps to change rules accordingly. Today ASTM is publishing basic principles of structural grading rather than grading rules and AREA is referring to commercial rules.

STANDARDS FOR GLUED LAMINATED MATERIAL

The past experiences in developing grading and structural grades were of much assistance in the establishing of glued laminated structural lumber specifications. Some of the earliest structural laminating was done in Scandanavian countries about 1911. The Forest Products Laboratory surveyed these structures, made tests and built experimental structures in this country and in 1939 published the first book in this country on the subject. It is entitled "The Glued Laminated Wooden Arch." This was the starter for what is now a large and growing industry.

The first and second industry standards for glued laminated structural lumber were published in 1946 and 1951 by the West Coast Lumbermens' Association. The Southern Pine Association has followed suit this year and two other associations are considering the same move.

Glued laminated lumber utilizes standard commercial grades of boards and 2-inch dimension, assembled together with glue to form any size member, many of them much larger than it is practical to supply in solid sawn timber today. It also makes possible special curved architectural and structural shapes.

The dispersion of growth characteristics, such as knots, throughout a member composed of many individual pieces, plus the ability to place the better pieces in areas in the assembled member that will receive the most stress, permits the assignment of higher working stresses than for solid sawn lumber. This makes for better utilization of lumber.

As laminations for gluing must be dry and as dry lumber in the thinner sizes will gain considerable in fiber strength, laminated members that will be used under continuously dry conditions are assigned even higher working stresses.

PREDICTED IMPROVEMENTS

The future development of structural grades and methods of grading will no doubt progress with greater rapidity than in the past. A prediction is that there will be two major changes: The first in the next decade and the second a decade later.

As to the first prediction: Though the growth of structural grades has been within our time, it has been a growth like that of Topsy. That which did not work well has been discarded and that which was practical has been retained. Each region, though it follows the basic method, has established structural grades with appropriate working stresses to suit its own species characteristics. There have also been changes from time to time to meet changing conditions. The result is, that even an individual grading rule will have a spread of grades with working stresses in increments of from 200 to 350 pounds between grades. Multiply such an illogical set up by the many grading rules of the regions and we find that working stresses for lumber are chaotic. Pity the poor architect or engineer in a market where many regions are competing.

A house cleaning is in order beginning with basic working stresses and the methods of evaluating the effect of growth characteristics on strength. Thoughts are being turned to this problem and a suggestion has been made that uniformity can be achieved by basing all factors on a geometrical progression of numbers. This appears to have merit, for most of the change will be accomplished on paper and the change in the mill segregation of grades will be slight.

Such a change will be of material benefit to the structural designer and a credit to the lumber industry. It works in this way:- All of the whole numbers and the grade ratios used in setting the strength values would be in a continuing geometrical progression. When a number representing a basic strength value is multiplied by a grade ratio, the result is another number in the geometrical progression--the working stress for that grade.

As the maximum and minimum basic strengths are known and the practical spread of grade ratios established by experience, it remains to select a geometrical progression that best fits all conditions. The resultant spread of working stresses would be met by species from all regions. The tabulated working stresses will be on a national rather than a regional basis. The designer will be able to select a working stress to suit design requirements. The result - no more chaos.

The second prediction is much more radical. It, too, has had some thought put to it but is as yet in the nature of dreams engendered by results that are incidental to experiments with other objectives in mind. This has to do with grading lumber by non-destructive methods of testing. Such a method will, no doubt, make use of a combination of devices - supersonic, electronic and mechanical.

Lumber will take a big step forward when such a method of lumber grading is realized, for then working stresses for average quality pieces can be safely increased by some 50 percent. Of necessity, present working stresses must be limited by the occasional low line piece than can occur, for such pieces cannot be eliminated by present visual inspection methods.

The lumber industry, lumber users and research technologists are urged to be alert for the clues which will eventually bring about the next grade step in structural lumber grading.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Tennessee Valley Authority's Interest in Forest Products Research

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THE TVA IS "charged" with the duty of constantly studying the whole situation presented by the Tennessee Valley, and the adjoining territory, with the view of encouraging and guiding in the orderly and balanced development of the diverse and rich resources of the region." This statement, contained in TVA's 1951 Annual Report, is from a document of the House Committee on Military Affairs on the TVA legislation and sets forth the framework under which TVA carries on its activities in dam construction, chemical research, and other specific resource development activities.

Forests and woodlands are an important factor in the "whole situation." They cover 54 percent of the land area, they grow yearly some 500 million cubic feet of wood, they support a $200 million forest products industry. With reforestation and the general adoption of better protection, management, and utilization practices, annual income from forest products can be increased over four times. The intangible values will rise accordingly.

We in TVA believe that how the job is done is equally as important as getting it done. I think, therefore, that you will be interested in knowing something about the approach TVA uses in its resource development work. Here is a brief outline of the organizational pattern under which we work and a description of the operating methods used.

The TVA Division of Forestry Relations[2/] represents the Authority's interests in the adoption of conservation practices affecting the production and utilization of timber products, watershed protection, and the development and management of forest, fish, and game resources. Its activities are carried on in collaboration with local, state and federal agencies, including the conservation departments, forestry divisions, and land grant colleges of the seven Valley states; the U. S. Forest Service, the U. S. Fish and Wildlife Service, and many others. The Division's headquarters are located at Norris, Tennessee. Field offices are maintained at Wilson Dam, Alabama; Asheville, North Carolina; Paris, Chattanooga, and Bristol, Tennessee.

The Division has three major branches: The Forest Development Branch conducts a cooperative field program of watershed protection and forest development in tributary watersheds, other special areas, and throughout the Valley as a part of TVA's over-all program of resource development. The primary elements of this program are demonstrations in forest protection, forest management, timber utilization, reforestation, and erosion control.

The Fish and Game Branch conducts the Division's program of restoring, developing, and utilizing the fish and wildlife resources of the Valley. It conducts surveys and technical studies of these resources and their environments, especially as the latter are affected by TVA reservoir development. The findings are then passed on to state conservation agencies for whatever action they think appropriate.

The Forestry Investigations Branch[3/] initiates and conducts such forestry research as is required to meet the needs of a program aimed at optimum forest resource development and utilization consistent with good watershed protection. Its major objective is to encourage and facilitate an integrated research program in forestry, including resources, products, industries, utilization, economics, management, influences, protection, and silviculture. To accomplish this objective, it works with and through established forestry research agencies and, where appropriate, with agricultural research agencies, making full use of all available facilities. It cooperates with other Federal and State agencies, and with local, privately endowed, industrial, and educational groups. It conducts or sponsors research as necessary to provide full information regarding forestry problems, forest conditions, and improved forestry practices. It acts as a regional clearing house for all such information concerning the Tennessee Valley area.

The Investigations Branch is further divided into three sections: Forest Economics, Forest Management Investigations, and Forest Utilization Sections. These sections have

Presented at Florida-Georgia-Alabama Section meeting, Valdosta, Ga., Oct. 5, 6, 1951.

2/ Willis M. Baker, Director, of Division of Forestry Relations, Norris, Tennessee.

3/ E. G. Wiesehuegel, Chief, Forestry Investigations Branch, TVA, Division of Forestry Relations.

administrative and technical responsibility for coordinating, conducting and supervising project activities within their specialized fields.

The TVA employs a minimum number of technical and administrative personnel to carry on forestry investigations, making full use of the cooperative and coordinated approach. Extensive use is made of the facilities and skills of other agencies as you will see in the summary of activities that follows. This approach eliminates much duplication of effort, gives maximum returns for each research dollar, and strengthens the research efforts of the local agencies.

Real progress has been made in commercial utilization during the past decade. Trees of lower quality and smaller sizes now have commercial value, but one out of every 10 sawtimber trees is still left in the woods because of defect or poor quality. Only about one-third of the wood from a tree cut for sawlogs actually finds its way into finished products. The low grade timber left in the woods and the waste in manufacturing processes (16 million tons annually) is the primary concern of TVA's forest products research program. We are seeking economic uses for more species and lower quality trees. We are interested in using more of the wood that is being grown. Fully adequate protection and intensive management of the forest resource will be achieved only if and when these unused portions of the forest resource are profitably utilized. Economic use of all products of the forest will provide the incentive for the degree of protection and management needed to attain the potential annual growth in the Valley of some 1,400 million cubic feet of wood.

Fact finding and investigations are not an end in themselves. The results of research must be interpreted and brought "down to earth" if they are to be effectively applied by the people who own and use the forest resource. TVA has from the beginning laid great stress on work at the "grass roots" and has made extensive use of the demonstration approach in getting across recommendations for better resource use.

An example of how this has worked in the forest products field is found in our timber and post treating project. Investigations in this field indicated that by using simple treating methods like cold soaking in pentachlorophenol and copper naphthenate, locally abundant post-size yellow pine from natural stands and plantations could be treated economically to meet the demand for durable fence posts. To get the results of this research to the people concerned, a portable treating plant was developed. Then, in cooperation with state forestry divisions and agricultural extension services, TVA conducted a series of treating demonstrations under the auspices of local sponsors.

Local farmers cut and peeled the posts and purchased the necessary chemical preservative. On a prearranged date the portable plant was moved to the demonstration site. Local farmer groups and individuals, invited to attend the demonstrations, learned first hand about post treating. More than 50 such demonstrations have been held. Attendance has passed the 12,000 mark. As a result, posts treated at these demonstrations are now in service on farms throughout the region; many small treating plants are in operation or under construction.

Over the years, TVA's invesitgations in the forest products field have covered activities ranging from comprehensive searches of literature on specific subjects to pilot-plant tests and full-scale commercial operations. This report is a summary or progress report of TVA's work in forest products research rather than a detailed technical discussion of specific projects. Activities are summarized under these major headings: Sawed products, derived products, laminated lumber, wood preservation and dry kilns. Published reports or manuscripts available for reference are summarized under these same major headings in the appendix.

SAWED PRODUCTS

The Tennessee Valley is an important timber producing region. Since 1900 it has turned out an average of about one billion board feet a year. In 1947 some 5,000 sawmills were locate in the 125 Valley counties. They produced 1.4 billion board feet of lumber and ties valued at $62 million. They furnished 4 million man-days of employment--equivalent to 16,000 full-time jobs--and paid out $21 million in wages. About $15 million was paid for stumpage. In many communities, sawmilling and logging provide the chief source of employment.

Small portable mills sawing less than 1 million board feet of lumber annually account for almost three-fourths of the total lumber production. Because the bulk of the Valley's timber is cut by small circular mills, their owners and operators have a tremendous influence on forest development and utilization. Their practices, good or bad, determine to a large extent the future of the Valley's forests and forest industries. Because of the key position

of the small circular mills in forest resource utilization a major part of TVA's forest products research is designed to deal with problems of this group.

Sawmill Study

TVA's interest in watershed protection and forest resource development led naturally to a study of small sawmills. Our aim was to improve sawmill efficiency--to get maximum production with minimum labor and equipment costs. We wanted to identify the things that mean greater profits to the operator, make for better utilization of the forest resource, and contribute most to the nation's mobilization program.

Briefly, here are some of the findings: Circular sawmills as a whole are not operated as efficiently as they could be; only 15 percent of the 58 study mills are run according to sound management principles. They saw too many small, non-profit logs--logs that yield lumber worth less than the cost of manufacture. Many mills are underpowered and lack such necessary equipment as edgers, spare saws, and log handling devices. They lose an average of two hours a day from shutdowns, most of which can be avoided. They operate only 120 days a year, less than half the number they could work.

Analysis of these facts indicates that most sawmill troubles could probably be corrected by better management. The results of the study were translated into practical, easily understood terms and distributed as widely as possible.

Log Grade Field Test (Forest Products Laboratory Grades Report D 1737)

In conjunction with the mill study an intensive log and lumber grade yield study was made during 1949-1950. This project was developed in cooperation with the Forest Utilization Service of the Southern Forest Experiment Station. Station personnel trained the TVA field crew in log grading techniques and made frequent inspections of its work to insure uniform application of the log grades.

The National Hardwood Lumber Association and the Southern Pine Inspection Bureau also participated in the project. Under a contractual arrangement with the TVA their inspectors were available to establish lumber grades for the sawed products.

Owners of 58 circular mills made logs at their mills available for study. Log and lumber data were collected for about 10,000 logs sawed during 100 days of operation at these mills. The net yield of sawed products was close to 600,000 board feet. About 7,000 of the logs and 470,000 board feet of the lumber was hardwood. Log and timber appraisal in this area, prior to the past decade, was based primarily on quantity rather than quality. This is understandable in that the supply of old growth or large mature trees of good quality was relatively plentiful. In the Tennessee Valley region during the 1930's the demand for hardwood lumber was met without utilizing trees of questionable quality and species. This was the era of so-called "high grading."

The old criterion of appraisal based on quantity in combination with personal experience and judgment is inadequate for determining dollar values for the changing timber resource. There is a well recognized need for a standard workable procedure for determining the value of the kind of logs that are available today. In fact, many of the trade associations and technical agencies have worked and are working with the problem now. As early as 1915 the Southern Log Association developed a system for grading hardwood logs based on the frequency of defect. This principle of grading is well suited to softwoods where the end product is construction lumber. It serves very well for grading yellow pine. Grades based on this principle have never been put into wide or general use for hardwoods, probably because they failed to adequately reflect timber values.

The Forest Products Laboratory grades are based on a somewhat different principle; namely, the "amount of clear area in the log." These grades bring together the results of several years' work in the various hardwood regions by the Forest Products Laboratory and several of the forest experiment stations. Our field test of them indicates that they offer a relatively simple and comprehensible procedure by which forest management, logging, and milling can be conducted on a predictable dollar and cents basis. They can be applied by the forest manager, the timber appraiser, timber buyer, log buyer, logger, mill operator, sawyer, or anyone else reasonably experienced in handling and working with timber and logs.

Logging Study

As a continuation of the sawmill study, a logging study got under way this year. It will deal primarily with the methods and conditions encountered in harvesting the logs that are sawed by circular sawmills in the Tennessee Valley area. Sample data will be collected all along the line from the stump to the mill. Findings of the study will be passed on to the operators by educational and demonstrational means, using our existing organization and cooperating agencies.

Tree Grade Study

Premium prices now being paid for high-quality lumber points up the need for a general, but sound, tree grading system. Our Forest Management Section has begun a study to develop tree grades applicable to the Tennessee Valley region. This involves measuring hundreds of standing trees, grading logs, and following the logs through the mill to get lumber grade output. What we are after is a system that will (1) classify trees according to grade, (2) assess the financial maturity of the tree, and (3) provide a basis for marking trees in accordance with the overall objectives of a management plan.

Other Studies

In addition to these activities, which are discussed in some detail because of their current status, we have conducted other studies that are of particular interest to the producer of sawed products. These include chain saw studies, development of a cutting guide, etc. Reports are available on this work and are listed in the appendix.

DERIVED PRODUCTS

Investigations in the sawed-products field are designed to develop improved methods of selecting the best trees to cut, of getting the logs to the mill, and of sawing the logs into lumber, and other products. Another objective of TVA's activities in the field of wood utilization is to develop profitable uses for the low grade timber left standing by previous loggers, and for those portions of the tree discarded in present manufacturing processes. These investigations are centered around chemically derived products.

Pulp and paper, the chief derived products of the region, have an annual value of nearly $40 million, or one-fifth the total value of all forest products. Further expansion in this field is needed. We particularly need more plants that can use hardwoods.

Wood Hydrolysis

In cooperation with the Forest Products Laboratory, TVA built a hydrolysis pilot plant at Wilson Dam, Alabama, for the production of molasses from hardwoods. In two years it has produced about 50 tons of molasses. The process used is the Madison wood sugar batch process--wood chips are hydrolyzed with a weak solution of sulfuric acid under pressure and high temperatures.

The molasses produced in pilot plant tests was distributed to experiment stations in seven states through agricultural agencies and the Utilization Service of the U. S. Forest Service. Preliminary results of feeding tests now under way suggest that hardwood molasses is a satisfactory supplemental source of energy in the rations of beef and dairy cattle.

Development of a technically and economically feasible process for producing wood sugars by hydrolysis would provide an outlet for large quantities of low-grade round wood and waste material and thus make for better utilization of the forest resource.

Tannin

New sources of tannin are needed to supplement rapidly diminishing supplies of chestnut, which in the past has supplied the bulk of tannin used by the American leather industry. TVA foresters, working with chemists from the University of North Carolina, found that high-grade tannin could be extracted from oak slabs --a waste product of Valley sawmills. It compares favorably with chestnut tannin in every way except cost; lower concentrations of tannin in slabs makes slab tannin two to three cents higher per pound.

Processes for separating bark from the wood were studied in the hope that most of this cost differential could be eliminated. A pilot plant was set up at Norris--a hog to chip the wood, plus screens and specific gravity separators for actually separating wood chips from bark chips. After much trial and error the investigators hit upon a procedure that yields a wood product 91 percent pure and a bark product 72 percent pure. From a standard cord of wood weighing 2,625 pounds (moisture free) they got 1,208 pounds of this wood product and 1,417 pounds of the bark product.

Preliminary results of tests run by the Eastern Regional Research Laboratory (U. S. Department of Agriculture) show that the bark product contains 7.7 percent tannin and that about 6.2 percent could be recovered in a normal commercial operation. This is getting pretty close to the 8 percent yield of chestnut wood.

From the U. S. Forest Products Laboratory --they ran tests on the wood product--comes the report that slab wood can be made into corrugating board that meets commercial standards.

On the basis of these tests, if only half of the oak slabs produced by Valley sawmills each year were made available, we could expect a yield of 21 million pounds of 25 percent tannin and 54 million pounds of paper pulp.

Essential Oils

Essential oils, valuable for masking objectionable odors in such products as soaps and greases, were extracted experimentally from the foliage of four Valley conifers--red cedar, loblolly pine, shortleaf pine, and Virginia pine. Steam distillation of fresh foliage harvested during the winter months from dominant trees of merchantable size produced yields ranging from 0.46 to 0.28 percent. Leaf oils are found in most North American conifers but commercial production is limited to a few northeastern species yielding from 0.4 to 0.6 percent. With somewhat lower yields from trees in this area, economic production will probably depend on the development of portable distilling equipment that can be taken into the woods to utilize the waste from logging operations.

Engineering scale tests have been made by the TVA Chemical Engineering Division, Wilson Dam, Alabama, to develop portable steam distillation equipment for extracting essential oils from forest waste. Red cedar sawdust was used for the tests because of its availability.

Tests of a continuous process show that a still giving satisfactory yields of cedarwood oil would be too large to be portable. The rate of distillation is limited to the rate of diffusion of oil and a long retention time is required.

Batch distillation of cedar sawdust was investigated using stills of 4 and 13 cubic foot capacity. Based on these tests a unit that could be mounted on a 6-1/2 by 20 foot truck or trailer bed was designed. It would extract 80 percent of the oil in cedarwood and could be expected to produce 51 pounds of oil per 8-hour day from fresh sawdust.

Lump Charcoal from Pine Sawdust

This work was a cooperative project between the Engineering Experiment Station of Alabama Polytechnic Institute and the TVA. A process for manufacturing a high-grade sawdust briquette from wood waste has been outlined and studied in detail. Variations in the process have been tested and optimum conditions determined. A practical, large-scale installation was outlined and the cost of the manufacture estimated.

Results of the experimental work indicate that high-grade fuel briquettes can be produced from southern yellow pine sawdust. They have many of the qualities desirable in a free burning fuel for domestic use.

Charcoal Gas Producer

Early in World War II TVA and the Georgia School of Technology cooperated on an Army contract calling for the development of a gas producer. A succesful model was developed and tested. Charcoal, as the solid fuel, produced gases suitable for use in internal combustion engines. Other carbonaceous materials such as wood, antracite coal, bituminous coal, low temperature coke, etc., can also be used to make producer gas. For gas-making purposes, however, charcoal is the best fuel because it has the highest reactivity. This makes for easier starting of the producer and greater flexibility of operation. The cost of a gas producer unit would be approximately $500 in terms of 1943 prices. From a fuel consumption standpoint, about 12 pounds of charcoal is equivalent to 1 gallon of gasoline. Economic studies and analyses made during mid-1940 indicated that the producer could not compete economically with liquid fuel for domestic use.

Black Walnut Shell Flour

Production of black walnut kernels in the Tennessee Valley region is an important industry--annual production is valued at $1 million. For the most part, farmers collect wild black walnuts and sell them to commercial cracking plants. Large quantities of walnut shell waste accumulate at these plants. Recognizing the utilization possibilities here, TVA conducted exploratory studies on grinding walnut shells into shell flour and testing its use in plastics and as glue extender. Uses for coarse ground shells were also explored, and production problems were analyzed. These tests were made in cooperation with industrial firms. Laboratory work was conducted by the University of Michigan. At least one plant in the region is producing shell flour on a commercial scale as a result of this work.

Miscellaneous

Literature searches have been made on a number of other possibilities in the general field of derived products. These include the use of acorns as food and feed; the fertilizer value of oak leaves; the use of extractives from the wood, bark, leaves, flowers and seed of several tree species (slippery elm, Ulmus fulva; American elm, Ulmus americana; sweetgum, Liquidamber styraciflua; blackhaw, Virburnum rufidum and j. prunifudim) as a source of tannic acid, medicinals, dye, gums, etc.; and the economic possibilities of wild herbs in the Tennessee Valley. Abstracts and lists of references on these subjects are available in our files.

TVA'S INTEREST IN FOREST PRODUCTS RESEARCH

LAMINATED LUMBER DEVELOPMENT

The laminated lumber project was jointly recommended by the TVA Commerce and Forestry Relations Divisions after consideration of numerous projects suggested by the U. S. Forest Products Laboratory. Several trade associations and interested private individuals were consulted and advised regarding the project during the course of development.

The objective was to demonstrate an economically sound process by which low-grade and short-length logs could be profitably utilized. The project included the design, building, and testing of a continuous type hot press to assemble and glue short, thin ply strips into a continous 12-inch board. It was also necessary to develop and test machines for producing the ply strips from small, short, low quality logs.

Such machines were designed, built, and tested through all stages of production from log to finished product in a TVA-operated pilot plant. These pilot plant tests and operations indicated the need for a full-scale commercial operation, and one was subsequently undertaken with a private firm. This commercial test revealed a need for further mechanical development in the glue press, which failed to meet expectations under continuous commercial operation.

The U. S. Patent Office issued a patent (No. 2,490,819, July 13, 1949) for "Making Laminated Lumber" to assignees of the Tennessee Valley Authority. Engineering services of a competent firm were contracted and a circulating ball type press was designed which would eliminate the operating difficulties encountered in the commerical try-out. This was the situation in December 1947 when the pilot plant was destroyed by fire. Budget limitations prevented our rebuilding it. However, tests already completed were believed to provide the data needed for the design of an economically sound and mechanically efficient commercial plant.

The prime objective of this project--commercial application of the process--has not yet been accomplished. However, certain positive contributions to wood technology and utilization have been made: (1) By using the better pieces on the top surface the three-ply construction gives a high-grade face and, from a market standpoint, "up-grades" the entire piece. (2) Highly stable glue bonds can be obtained in a continuous press in the short time required for commercial production. (3) The product is attractive, strong, dimensionally stable, and performs well in service. (4) Use tests demonstrated important economies in laying cost as compared with standard flooring.

We are still working with industry in an effort to get the process into commerical operation. Right now two industrial groups are actively interested in the process and have had discussions with us regarding use of the process.

WOOD PRESERVATION

Rot, termites, and beetles of various kinds attack wood in exposed installations and materially reduce its service life. Durable woods like black locust, cedar, etc., are not available in adequate quantities in many sections of this region. This fact, coupled with increased fencing needs and inflated labor costs, has led to a search for practical, inexpensive methods of prolonging the life of fence posts and other timbers. Over 13 million posts and one million man-days of labor are required annually in the maintenance of Valley farm fences. Maintenance costs approximate $15 million a year. Much of this expense could be saved if more chemically treated posts were available to landowners at prices they could afford to pay.

Throughout the Valley there is an ample supply of non-durable, post-size trees. Removal of some of these trees in systematic thinnings would actually benefit the woodland, especially the thousands of acres of natural and planted pine. A recent report of our Forest Management Section indicates that during the next five years, some 60 million posts could be cut from pine plantations established with TVA trees during the past 17 years. Thus our effort in wood preservation is two-fold: (1) to increase the service life for wood; (2) to create an economic use of a heretofore unused portion of the forest stand.

Coordinated Studies

To promote the use of treated wood, TVA initiated a regional fence post preservation project in cooperation with six land grant colleges (University of Tennessee, Alabama Polytechnic Institute, Virginia Polytechnic Institute, North Carolina State College, University System of Georgia, and Mississippi State College), the U. S. Forest Service, and several chemical companies. Its purpose is to test inexpensive preservation methods applicable to farm use. To date over 11,000 posts (4 pine and 23 hardwood species) have been treated with pentachlorophenol and cooper naphthenate. Most of these posts are in the ground for service testing. Two new test

projects will begin next year: treating with zinc chloride and peeling hardwoods by the application of chemicals to the standing tree.

In addition to the preservative tests, the group has also studied the effectiveness of insect peeling, including the effects of insect peeling on the strength properties of posts. Standard test plans were used by the several agencies doing this work. Results indicate that with proper control, insect peeling reduces the peeling cost without weakening the post.

Detailed information on work plans and progress is contained in the minutes of the annual meeting of the cooperators.

Mobile Treating Plant

Mobile timber treating equipment was designed and developed for demonstration purposes. Readily transportable, the outfit is designed to demonstrate both the cold-soaking and the hot-and-cold bath methods of preservative treatment. Two trailer-mounted tanks, equipped with an overhead hoist, are pulled by a truck which carries 650 gallons of treating solution, a power pump for transferring the preservative to and from the treating tanks, and heating torches.

Post Peelers

Two types of fence post peeling machines developed and tested by TVA have proved highly successful for farm and community use. Specifications, including detailed drawings, bill of materials, and a descriptive report are available for a tight chain post peeler. This machine peels pine posts at an average cost of less than 4 cents per post. The other peeler, a drum-type, is towed on a trailer by the same jeep that furnishes power to turn the drum. It peels posts twice as fast as the chain peeler. Operator fatigue is less. Peeling costs average less than 2 cents per post. Reports indicate that a number of both types of peeler have been constructed and are in use at this time. A patent for the chain type peeler was issued to the Tennessee Valley Authority in May 1951. Two manufacturing concerns have requested licenses to produce it commercially.

Pilot Plant

To provide answers to some of the problems encountered by operators of small commercial treating plants, TVA designed and built a pilot plant at Norris. Equipment includes a cold soaking tank, a hot tank, mixing and storing facilities, and the necessary testing instruments. Initial test runs on pine posts indicate that with the present equipment and a one-man crew, production will average about 2,000 treated posts a week. Information now being collected on heat transfer within posts will help establish schedules for hot bath treatment. At least six small treating plants have been constructed on the basis of plans and recommendations developed from this plant.

Treatability Test for Pine

Early experience indicated a wide range of variation in the rate of absorption and depth of penetration of preservatives in the cold-soak process. A review of literature failed to supply the answers. Accordingly, controlled tests were run to measure the effect of temperature differential between wood and solution, wood density, moisture control and surface condition of pine posts on absorption and penetration. These data are currently being analyzed and will be reported at an early date.

Double Diffusion Process

Cooperating with U. S. Forest Products Laboratory, we also conducted experiments in the preservative treatment of fence posts by the double diffusion process. Developed by chemists of the Forest Products Laboratory, the process involves steeping green wood successively in solutions of two chemicals. The chemicals thus separately diffused into the wood then react to deposit a relatively insoluble toxic compound. This treating and service test, involving some 500 posts, was made in 1947. Annual inspections made since that date indicate that the process has promise as an effective method of treating posts.

KILN DRYING

An experimental electric kiln for drying lumber was constructed by Stair Technical High School, Knoxville, with the help of the U. S. Forest Products Laboratory and TVA. Built primarily to supply dry lumber for the school's woodworking shop, the kiln is also used to train kiln operators and to test the efficiency of electricity as a heat source for drying lumber.

TVA's interest in the project was two-fold: Development of a low-cost kiln would mean more local processing and better quality control for small woodworking shops in the region. In addition, it was an opportunity to test another industrial use for electricity. Working with technicians of the U. S. Forest Products Laboratory, TVA electrical engineers and foresters designed the kiln; it was built by veteran trainees enrolled at the school. It is the forced-air-circulation type and has a gross capacity of 3,500 board feet. It is unique in that it can be operated with either steam or electricity; both can also be used simultaneously. Total cost of materials, plus electrical work done on contract, was

approximately $4,000. Eight months of kiln operation showed that well-conditioned lumber can be produced at a reasonable cost when all factors are considered. Drying costs depend on the kind and thickness of the wood and its initial moisture content. Although they are higher than for large steam kilns, results so far indicate that the small electric dry kiln may have a definite place in the wood-working industry. The convenience of being able to dry small quantities of wood, as it is needed, offsets to a large extent the higher drying costs of the small kiln.

CONCLUSION

As you have noted from the foregoing summary, we are not engaged in conducting fundamental research. Our effort is primarily concerned with applied research. Through the cooperative approach, we are making full use of all available facilities, seeking the application of research to those problems peculiar to the Valley. We are endeavoring to meet fully our responsibility for "constantly studying the whole situation with the view of encouraging and guiding in the orderly and balanced development of the forest resources of the region."

Today, TVA's program, like that of other federal and state agencies and institutions as well as private industry, is undergoing many changes; changes that are forced upon us by world conditions--conditions that none of us like or want, but which must be met with determination. Our major emphasis now is of necessity, and rightly so, directed toward those activities that relate directly to support of the rearmament program or essential civilian needs. Despite the budget limitation with which we are faced, we have so far been able to keep most of our technical staff intact. And while no new projects are contemplated in the immediate future our organization is flexible and we can make adjustments if and when the need arises. In the meanwhile we have a big job before us in getting into use the results of our past work in forest products research.

The emergency will continue to make heavy demands on our forest resources. These demands, coupled with increasing shortage of manpower and the threat of losing foreign sources of many products, emphasize the need for making maximum efficient use of our forest resources.

An example of how the present emergency affects the economic possibilities of some of TVA's work in forest products research is found in the price of molasses. When the wood hydrolysis work was started in 1948 some molasses from sources outside the U. S. were available at ports of entry for around 6 cents per gallon. In competition with prices such as these there was little hope that production of wood molasses would be economic. The situation is very much changed today. Molasses from the same source are now priced at 30 cents per gallon. Preliminary cost studies of the process tested in the pilot plant at Wilson Dam indicate that wood molasses can be produced for considerably less than this. Thus it may well be that in the not too distant future the forest may be our most economic source of molasses for use as feed and fermentation.

The big job ahead in this region is in the field of secondary processing. We need to produce more finished products in the region if the forest resource is to make its maximum contribution to the economic betterment of the region.

APPENDIX

List of Tennessee Valley Authority Forest Products Research Reports and Manuscripts, etc.

This listing includes activities in which TVA has participated in the general field of forest products research. The results of all TVA forest products research are available for public use. Where published reports or papers are indicated they are usually furnished to bona fide interests without cost. Manuscripts and preliminary reports are usually available on a loan basis or information contained therein may be obtained by conference with members of the TVA staff. State and federal agencies, industrial representatives and individuals are invited to contact members of the TVA staff regarding subject matter of interest to them.

Sawed Products

A Recommended Cutting Guide for Sawtimber Stands in the Tennessee Valley. 1943. Technical Note No. 4 - Division of Forestry Relations.

Selling Price and Production Costs in the Tennessee Valley. (Lumber) By Robert A. Campbell, Journal of Forestry, September 1944.

Power Chain Saws and Manual Crosscut Saws in the Production of Hardwood Logs. By F. C. Becker, Jr., Division of Forestry Relations. Reprint Southern Lumberman, January 15, 1946.

Effects of Log Size and Grade on Production Rate and Lumber Grade in Shortleaf Pine. 1949. By W. N. Darwin and B. C. Cobb, Division of Forestry Relations.

A Basis for Comparing the Value of Southern Yellow Pines for Lumber and Poles. Technical Note No. 7, Division of Forestry Relations.

Yellow Poplar Lumber Grade Yield Recovery: A Guide to Improved Cutting Practices. Manuscript 1950. By G. H. Fechner, Division of Forestry Relations.

Utilization of Beech Timber in the Tennessee Valley. 1950. By Forest Utilization Section. Manuscript. Division of Forestry Relations.

Good Management: Key to Sucessful Sawmilling. 1951. By W. N. Darwin and A. K. Thurmond. Reprints from Southern Lumberman.

Sawmill Facts. 1951. By Forest Utilization Section, Division of Forestry Relations.

Circular Sawmills in the Tennessee Valley Region. 1951. By Paul H. Lane, Division of Forestry Relations. Reprints from Forest Products Research Society.

Production of Sawed Crossties in the Tennessee Valley Region. Manuscript 1951. By Paul H. Lane and G. H. Fechner, Division of Forestry Relations.

Plan of Work for Logging Study, Tennessee Valley Region. 1951. By Forest Utilization Section, Division of Forestry Relations.

Plan of Work for Survey and Evaluation of Lumber and Timber Production by Small Mills in the Tennessee Valley. 1949. By Forest Utilization Section, Division of Forestry Relations.

Derived Products

Utilization of Wood Wastes Through Hydrolysis. By Nathan Gilbert, I. A. Hobbs, J. D. Levine, and A. B. Phillips, TVA Division of Chemical Engineering. 1950.

Wood Wastes in the Tennessee Valley and Their Chemical Utlization. By Lowell F. Bailey, Division of Forestry Relations. Reprint Journal of the Tennessee Academy of Science, April 1947

Tannin and Secondary Products from Oak Slabs. By L. F. Bailey and W. H. Cummings, Division of Forestry Relations. Reprint Journal of the American Leather Chemists Association, May 1948

Pine Bark as a Source of Tannin, by E. A. Snow, Division of Forestry Relations. Reprint Journal of the American Leather Chemists Association. July 1949.

Tannin from Oak Slabs, by E. A. Snow and L. F. Bailey, Division of Forestry Relations. Reprint Journal of the American Leather Chemists Association. October 1949.

Leaf Oils from Tennessee Valley Conifers, by Lowell F. Bailey, Division of Forestry Relations. Reprint Journal of Forestry, December 1948.

Development of Portable Equipment for Production of Essential Oils from Forest By-Products; Cedarwood Oil by Steam Distillation of Cedarwood Sawdust. 1950. TVA Division of Chemical Engineering.

The Production of Lump Charcoat from Sawdust Without a Binder, by C. A. Basore and Robin A. Russell, Bulletin No. 12, Engineering Experiment Station, Alabama Polytechnic Institute.

Gas Produced Conference. A summary report of development work by Engineering Experiment Station, Georgia School of Technology. October 8, 1943.

Exploratory Studies of the Grinding of Black Walnut Shell Flour and on its use for Plastics Filler and Glue Extender. 1949. By Thomas G. Zarger, Division of Forestry Relations.

Manuscripts covering the results of extensive search of literature on the following subjects by the staff of the Forestry Relations Division are available. These reports are concerned with uses for secondary products such as oils, gum, exudates, flower, fruit, leaves, etc. 1944.

Acorns	8 pages	31 references
American Sweet Gum	3 "	27 "
Blackhaw Viburnum	1 "	5 "
Camphor Tree	3 "	30 "
Red Cedar	4 "	25 "
Oak Leaves & Litter (as fertilizer)	3 "	25 "
Slippery & American Elm	2 "	21 "
Sassafras	3 "	29 "

Economic Possibilities of Wild Herbs in the Tennessee Valley. 1944. By Jacqueline S. Schermerhorn, Division of Forestry Relations.

Laminated Lumber

Laminated Lumber from Low-Grade Hardwoods: Production Data from Pilot Plant and

Production Cost Estimates. 1946. By B. A. Batson and R. D. Lambert, TVA

Laminated Lumber from Low-Grade Hardwoods by the continuous Glue Press Process, by B. A. Batson, Forestry Relations Division. 1949.

Lamination in Cross-Laminating of Oak Under Extreme Service Condition (exposure test). 1947. By E. G. Stern, Virginia Polytechnic Institute, Engineering Experiment Station Series No. 66.

Design and Specifications for Circulating Ball Type Continuous Lumber Laminating Press, by Hughes Hall, Tennessee Valley Authority, 1951.

Making Laminated Lumber. U. S. Pat. 2,490,819. By R. D. Lambert and Daniel W. Smith. Assigned to TVA. 1950.

Completion Report, Laminated Lumber Development. 1951. Division of Forestry Relations.

Post and Timber Treating

Project Plan, Fence Post Investigations in the Southeast. Joint plan, State Agricultural Experiment Stations and Tennessee Valley Authority, 1947.

Appendix A - Pentachlorophenol Test. 1947.

Project Plan, Bug Peeling of Pine and Hardwood Posts. Joint plan, State Agricultural Experiment Stations and Tennessee Valley Authority. 1949.

Minutes of the Coordinated Fence Post Preservation Investigations in the Southwest. 1947, 1948, 1949, 1950, 1951. Joint report of cooperating agencies.

Studies of the Double-Diffusion Process of Treating Wood: The Treating of Fence Posts at Wilson Dam, Alabama. 1948. By R. H. Baechler, U. S. Forest Products Laboratory.

Illustrated Lecture Material used in Fence Post Treating. By E. M. Conway and R. L. Schnell, Division of Forestry Relations. 1949.

A Mobile, Open-Tank Plant for Treating Posts and Timber. 1950. By W. N. Darwin Division of Forestry Relations.

A Tight Chain Post Peeler, by W. N. Darwin, Division of Forestry Relations. 1950.

A Portable Drum Post Peeler. By E. M. Conway and R. L. Schnell. 1951. Division of Forestry Relations.

Progress Report, Fence Post Investigations. Joint report, State Agricultural Experiment Stations and Tennessee Valley Authority, 1950.

Resilient Chain Post Peeler. 1951. U. S. Pat. Office, Pat. No. 2-552-526. By William N. Darwin; assigned to TVA.

Status Report, Fence Post Studies. Division of Forestry Relations, 1951.

Kiln Drying

An Experimental Electric Kiln for Drying Lumber. By W. W. Jolly and J. H. Stanfield, Tennessee Valley Authority. Reprint, Southern Lumberman, May 15, 1949.

Lumber Dry Kiln Prospectus for Graham County School System, Robbinsville, N. C. Manuscripts and diagrams by Paul H. Lane, Division of Forestry Relations. 1951.

Lumber Dry Kiln Prospectus for Maness Manufacturing Company, Bryson City, N. C. Manuscripts and design drawing by Paul H. Lane, Division of Forestry Relations. 1950.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

The Application of Aerial Photographs to Forestry

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INTRODUCTION

THE FIELD OF FORESTRY as we know it today embraces many sciences. A knowledge of these sciences and their application to forest management problems is becoming more important to forest industry daily. The lattest science to be applied to forestry is Photogrammetry. Indications are that the application of this science will bring about many changes in the practice of forestry.

PHOTOGRAMMETRY

Photogrammetry literally means taking precise measurement from photographs. While it is often thought of as dealing only with aerial photographs, where it finds greatest application in forest management, it actually includes photographs of any object taken from any vantage point.

History

While photogrammetry is relatively new to forestry it is not new in its application to other fields. Experiments dealing with photogrammetry were undertaken in 1849 in France. Many of the present techniques employ the findings of these early experiments. Interest and knowledge spread until the International Society of Photogrammetrists was organized in 1910, but it was not until 1934 that a separate organization was started in the United States.

As in many other scientific fields, practical application of aerial photogrammetry was accelerated by developments that took place during the two world wars. The Germans made great advances during World War I in the use of aerial photos for reconnaissance work, and developed instruments for applying aerial photographs to other purposes. Between World War I and World War II aerial photographs were used so widely and so many improvements were made in their application that photogrammetry became the accepted basis for virtually all large mapping projects.

Presented at meeting of Florida-Georgia-Alabama Section, Forest Products Research Society, Valdosta, Georgia, October 5-6, 1951.

Use

As a result of the advancements that were made during World War II aerial photographs are used today in practically all fields dealing with surveying and study or use of the earth's surface. Aerial photographs have been used to great advantage in forestry, geology, soil conservation, flood control, highway, railroad, and utility location, mining, and many other fields. Today, 40 percent of the 145 institutions offering courses in surveying also offer courses in photogrammetry.

Forest Photogrammetry

Paralleling the development of photogrammetry as a science was the development of the ways in which the basic fundamentals of photogrammetry could be applied to forestry. Shortly after World War I German foresters developed several complicated and costly instruments for taking measurement from aerial photographs for forestry purposes. Many of these instruments were never developed beyond the experimental stage but aroused the interest of foresters the world over. Canadian foresters simplified and improved several of these early German instruments and adapted them for use in the forests of North America.

Foresters of the United States gave very little attention to aerial photographs as a tool until shortly before World War II. As a result of improvement in the techniques of handling and interpreting aerial photographs, their use in forestry in the United States has shown a tremendous increase since the war.

Forestry work does not call for the high degree of precision demanded in engineering photogrammetry. Here, accuracy in terms of mapping error is not as important as accuracy in terms of photographic interpretation. Forest mapping will perhaps always be crude in comparison to the work of the professional photogrammetrist. To the civil engineer or mapping expert photogrammetry is an end in itself whereas to the forester it is just a means. It is just another tool, but one that many foresters believe will find considerable use.

APPLICATION OF AERIAL PHOTOGRAPHS TO FORESTRY

FORESTRY USES

An aerial photo is not a map but a true, pictorial representation of the visible objects of the earth's surface. Features appear in proper perspective and not distorted in size, as is often the case with standard map symbols. The aerial photograph, taken from its elevated vantage point, provides a detailed record of the complex appearance of the earth's surface impossible to obtain by ground survey methods. This wealth of pictorial information may be expanded and made more intelligible by use of the stereoscope and other photogrammetric instruments.

To yield desired results, aerial photographs must be interpreted properly. When properly interpreted they are useful in practically all forestry activities. They may be used in all types of mapping; inventory; silviculture; protection; logging; improvement work such as roads, bridges, and buildings; records; land acquisition; and many other activities.

The newest and perhaps the most promising way in which aerial photographs may be used in forest management is for timber stand inventory purposes. After the last war, as a result of the heavy drain imposed on our forest for war materials and also because of the curtailment of periodic inventory during the war, a reinventory of many of our forest stands was needed. In times past, when the timber supply seemed limitless, a rough estimate of timber volume could be utilized with little chance of bankruptcy as a result of minor errors. With an increase in the value of timber it became apparent that closer estimates of volume were necessary. Not only was there a greater need for more accuracy and detail, but the cost had to be kept to a minimum. Aerial photographs offered a solution to these problems and received considerable attention, particularly in connection with timber stand inventory.

Application

By proven interpretation methods there are a number of factors, necessary in many phases of forest management, that can be determined about a forested area directly from the photographs with a minimum of ground work.

Species - By a proper correlation of ground work with a detailed stereoscopic study of the photographs it is possible to identify many species of trees. Some of the aids to species identification are: tone, texture, crown shadow, crown size, and location of trees with regard to topography and tree height.

Site - By a proper correlation of ground work, knowledge of forest sites, and a detailed stereoscopic study it is possible to evaluate site quality utilizing topography, tree height crown-diameter ratio, vegetation, and other visible features.

Density - The density of a stand in number of trees or crown closure percent can be measured or estimated quite accurately.

Tree height - By one of several methods it is relatively easy to measure tree height to a reasonable degree of accuracy.

Crown diameter - For correlation with tree height crown diameters can be measured quite accurately. Such measurements are useful in the construction of local volume tables for stand volume determination.

Area - For a given stand, timber type, or total forest, the area can be quite readily and accurately determined by one of several methods directly from the photographs or map made therefrom.

In addition, combined with a proper amount of field work, several things can be determined indirectly from the measurements listed above. These are: stem diameter, basal area, stem form, and stem quality.

Inventory

Aerial photographs as used in forest inventory do not eliminate field work, but reduce it to a minimum consistant with desired accuracy.

While aerial photographs are very promising in the field of forest inventory they also have definite limitations. They cannot provide all of the information needed for inventory work but much information can be supplied at lower cost and with greater accuracy. Exact and completely acceptable procedure is still in the formative stages but there are several general methods in which aerial photographs may be applied to forest inventory.

1. In conventional ground inventory methods aerial photos are often used in the construction of planimetric and timber type maps and as aids in the movement of field parties from one plot to another during the collection of the field data.

2. Aerial photos may be used to control the ground cruise. This method, which utilizes the photographs to a greater advantage, is used by a number of forest management organizations including the U. S. Forest Service. A detailed planimetric and type map is first constructed by photogrammetric techniques; applicable to the

the speed and degree of accuracy that is required in forestry work. From the type map, so constructed, the areas of the various types of the forest are determined. By utilizing the size of the area, approximate value of the timber per acre, size of the timber, density of the timber and variability within the type, the number of plots required to obtain a desired degree of accuracy is determined for each type. In this way a more intensive cruise is run on the more valuable timber types and the number of plots for a type of little value is held to a minimum. The location of these plots is usually done in a definite, systematic manner but in such a way as to reduce the amount of travel common to the conventional line plot systems. The type of information taken on each plot is similar to the data obtained in conventional cruising. The percent cruise necessary for a given degree of accuracy is much lower than in conventional cruising since each type is considered as a homogenous unit.

3. The third type of inventory, in which only the aerial photographs are utilized, has not as yet been employed to any great extent. In this procedure ground work is practically eliminated in that all necessary measurements are taken directly from the photographs. Preliminary ground work is needed only in order to establish correlation between the measurements taken from the photographs and the actual ground measurements. This method, while showing great promise, is still in the developmental stage.

Protection

Aerial photographs have been used for forest protection purposes longer than they have been used for inventory work. They can be quite easily applied in the work of protecting the forest from fire, insects and disease. In this regard, their use as an aid to fire protection is most important.

From aerial photographs a trained interpreter can construct vegetative type maps in order to determine hazard areas and to help estimate direction and anticipated rate of spread of forest fires. Also, topographic maps, prepared from photographs, are useful in determining methods of attack in fire suppression. Location of roads is facilitated, fire towers can be located to best advantage, fire lines can be placed so as to take full advantage of existing barriers and damage can be appraised after a fire.

While photographs are seldom useful in the direct location of diseased areas or insect infected areas unless specifically made for this purpose, they are useful in combating both disease and insect infestation. Best access routes to remote areas can be determined from aerial photographs as well as boundaries to be used in setting up quarantines. Crews are easily assigned to work areas directly from the photographs and records of infestation and control measures can be made on the prints.

Silviculture

In silviculture operations, such as planting, it is quite easy to locate areas in need of planting, to determine extent of such areas, to lay out planting work and to make permanent records of planting. In cultural operations, areas in need of thinnings may be readily located. Such operations are easily directed and permanent accurate records can be made directly on the photographs.

Administration

Photographs are a handy tool in the administrative work necessary in the management of a forest. The old timer, whose chief asset is a forest knowledge gained from long years of association with a particular area, is no longer indispensible. With the aid of photographs a person can become well acquainted with a large area in a relatively short time. If photographs are available, many trips to the woods are eliminated in making decisions and determining certain facts pertinent to forest management. Accurate permanent records are easily kept directly on photographs and work instructions are easily and plainly given when aerial photos are used for illustration.

Logging

Photographs are highly useful in logging operations, in determining location of operable timber stands, routes into seemingly inaccessible areas, and location of logging roads.

Photographs find use in many other phases of land management. They may be applied in: acquisition, range management, damage surveys, research and other phases.

Questionnaires were recently sent to a number of forest products industries in Florida, Georgia and Alabama concerning the application of aerial photographs to these particular industries. Almost all operators were using aerial photographs for one purpose or another. Cruising, acquisition, logging, fire suppression and presuppression, silviculture, road location, timber sales, planting and all types of mapping were among the various uses reported. Most of these operators did not start utilizing aerial photographs until after the war. Formal training of operating personnel varied from little or nothing to several courses in interpretation given by recognized forestry schools. The problems that these companies have met with are quite varied. In most instances there seemed to be a definite desire to learn more

of the application of aerial photographs and ways of utilizing them to greater advantage.

PROBLEMS

Cost

Though aerial photographs are assuming a wider use each day in forest management practices there are still a number of unsolved and pressing problems. One of these is the excessive cost per acre of having aerial photographs flown specifically for forestry application. This is not a problem of large land owners but often prevents small land owners from using photographs. Because of the technical training and equipment needed for taking aerial photographs and the time element in waiting for good flying weather, costs are often too high for a project to be undertaken unless large areas are involved. However, the expenditure for equipment needed in utilizing the photographs after they have been taken can be kept at a reasonable figure even for the smallest operation. Interpretation teams can acquire operating skill, directly on the job, in a relatively short time.

Existing Photos

The high cost of aerial photographs is often overcome by utilizing existing photographs. Approximately 70 percent of the United States has been photographed from the air at one time or another by one of the many governmental agencies or by one of the several commercial aerial photographers of the U. S. These available photographs are used quite often by forestry enterprises even though some cannot be used to their fullest advantage because of incorrect scale, incorrect film type, incorrect season, or perhaps because they are too old. Existing photographs should be used when possible in order to effect the savings offered. Care must be exercised in their use, however, since the afore-mentioned factors will have a definite bearing on the accuracy of the results.

Species Identification

The delineation of type boundaries and area are very easily and accurately determined as are the densities and size classification but consistant accuracy in species indentification is in some cases quite difficult even with high quality photographs. In some areas species identification is quite easy while in others gross volumes are more easily arrived at than the correct species identification. This problem is constantly being studied by private forestry, U. S. Forest Service and aerial photographers.

CONCLUSIONS

Much more research is needed before photographs may be put to their highest possible use in forestry. We need information concerning the proper scale for particular types of work or particular areas; proper film and filter combinations for facilitating species identification; new methods, techniques and instruments for increasing the accuracy and speed of all phases of the work; and ways in which the flying and processing of photographs can be made less expensive.

When considering the application of aerial photographs it is quite apparent that tremendous progress has been made during the few short years they have been in use. In most phases of forestry work they seem destined to fulfil a definite need. Today they are a highly useful tool --tomorrow they will undoubtedly be considered indispensible.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Valuation of Ponderosa Pine Stumpage by Use of Tree Grades

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MANY METHODS for the valuation of ponderosa pine timber have been devised, but most of them are too complicated and difficult to apply. When one considers that a cruiser is expected to gather timber volume, and silvicultural and engineering information, it is no wonder that he sometimes slights quality valuation data. However, in these days of thirty-dollar and forty-dollar ponderosa pine stumpage it behooves an operator to examine the quality factor carefully. Industry needs a set of grading rules that are simple in construction and easy of application. The grading rules described below were set up with objective in mind. They are based on long observation of the ponderosa pine trees during the various stages of growth when the tree develops the natural characteristics that affect lumber grades.

PONDEROSA PINE TREE GRADES

In the development of these tree grades, the age of the tree is a primary consideration and its position in the stand a secondary one.

We can co mpare the ponderosa pine tree to a human being. They both have their childhood, teen-age, maturity and overmaturity or security. In addition, we find misfits and morons. Knot characteristics and relative position are probably the most important considerations in determining lumber quality. Sound or live knots come from live branches, while encased or loose knots come from dead branches. The age of a tree and its position in a stand, therefore, greatly influence the amount of live-knotted material produced. Young bull pine trees are usually tight-knotted and are designated Grade 3. As the young bull pine advances into the teen-age, or older bull pine stage, some of the lower limbs die from lack of light, and the trunk grows around the stub. Trees of this age class produce black or loose-knotted lumber of a lower grade and are designated Grade 4. As trees reach maturity, the dead limbs drop off and clear wood grows on the trunk. Many years after the natural pruning process has been completed, the trees become Grade 1 producing select lumber. On the other hand, trees that do not prune themselves quite completely and have a widely-spaced knot arrangement make Grade 2 trees, producing shop lumber when they reach maturity or overmaturity.

Among the mature and immature trees, we have a third tree type which, unlike the select trees, is rather limby and, unlike the shop trees, has its dead limb stubs more closely spaced. This tree produces a mixture of lumber grades and is a Grade 5. It is the most common tree in mature stands and, from the standpoint of evaluating ponderosa pine timber, can be regarded as the average or par tree. Most significant, from the standpoint of the method described here, is the fact that the average selling value of lumber produced from a Grade 5 tree currently approximates the regional millrun price of ponderosa pine lumber.

A fourth category of mature trees is the defective or wolf-type trees which are grouped in Grade 6. This category also contains the crippled and rotten trees and those that are genetically speaking, the morons. Most of the lumber from these trees is No. 4 and No. 5 Common.

The following tabulation shows the value of each of the six tree grades in relation to the Grade 5, or average tree. For example, a Grade 1 tree produces lumber which, on the average, is 35 percent more valuable per thousand board feet than lumber from Grade 5 trees.

Grade	Relative value per thousand board feet
1	135
2	115
3	95
4	80
5	100
6	70

Tree grades are pictorially presented in Fig. 1. Several hundred trees were graded to determine the forms shown in this figure as well as the age, size, and other characteristics shown in Fig. 2.

APPLICATION OF TREE GRADES

Tree grade data can be taken during a volume cruise, but it is preferable to make a valuation

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survey when logging and other appraisal data are taken. Furthermore, after examination of the volume data, one is in a better position to determine a sound and adequate quality sample. Timber quality is recorded usually on 1/5 acre plots with a plot interval of five to ten chains, plot interval depending, of course, on the size of the area. On a regular shaped timber area of small volume, a random line through the area is possible preferable.

A sample case of application of tree grades and determination of average selling value of the lumber sawn from the timber is presented in Table 1. The timber on Big Pine Creek contained a separate area of young growth and, therefore, the quality appraisal was given separate consideration. The table presents data on the old-growth which constituted about 95 percent of the stand.

Table 1 shows that 41.8 percent of the volume in this stand is in No. 1 trees, or somewhat better than the average for ponderosa pine timber, while only 2 percent is in No. 2, or shop grade, trees. As is usual there is a dearth of shop trees where there is a large volume in the No. 1 tree grade.

Similar data are shown in Table 2 for the young timber area of Big Pine Creek.

The next step in the application of tree grades is shown in Tables 3 and 4. The average selling price of ponderosa pine F.O.B. mill (all grades combined) can be determined from local sources or from the Western Pine Association. Since the average selling value of lumber from Grade 5 trees is practically the same as the current mill value of all ponderosa pine cut in the region, the Grade 5 tree is assigned the selling value of $80 per M. The value per M board feet of the other tree grades are determined by multiplying $80 by the percentage factors presented in column 1 of Tables 3 and 4.

These values are then weighted by the percentage of volume of each tree grade. For instance, Table 3 shows 41.8 percent of the old-growth volume in Big Pine Creek to be in Grade 1 trees. Hence, 41.8 percent times $108 equals $45.14, the weighted selling value per M feet, lumber tally, of lumber produced from Grade 1 trees. By carrying out this same calculation for all tree grades, an average selling value per M, lumber tally, of $90.42 is obtained for the old-growth lumber, and $68.25 for lumber produced from the young-growth timber. This is quite a spread. Weighting these values by the percentage of old-growth and young-growth contained in the Big Pine timber chance, an average selling value of lumber produced from the entire stand was obtained. The calculation is as follows:

Percent old growth - .945 x $90.42 = $85.45
Percent young growth .055x 68.25 = 3.75
Weighted average selling value per M of lumber produced from the Big Pine chance = $89.20 or $9.20 over the current average price of Ponderosa Pine lumber.

This selling value must then be worked back to the stumpage value by the customary appraisal methods. Any company using this system would naturally incorporate in the calculations its own production cost, profit margin and over-run figures.

SOME ADVANTAGES AND DISADVANTAGES OF TREE GRADES

Naturally, there are disadvantages to the system and some relative inaccuracies, but it appears that to a great degree, these are mutually compensating. Nothing in the biological world lends itself to exact mathematical calculation and solution, and the ponderosa pine forest is no exception. The more we strive for accuracy, the more involved become our calculations, until the system falls of its own weight and the appraiser cannot see the forest for the trees.

Regarding inaccuracies, we know for instance that over-run varies with log and tree size. To apply a different correction factor for over-run to each tree grade would be a needless complication unless one were dealing with an unusually abnormal dispersion of tree size and form that is rarely encountered. On the advantage side, the system is simple and can be mastered by anyone with a reasonable knowledge of ponderosa pine timber, lumber, and simple arithmetic. The foregoing application of tree grades to average selling value per M of lumber may seem complicated, but it is simple when compared with other methods that have been proposed.

SUMMARY

The five steps in the method of determining selling value of lumber produced from ponderosa pine timber are:

1 - Determine the size and character of the sample by examination of the cruise data.

2 - Determine percentage of volume of different tree grades in each timber unit.

3 - From local sources or Western Pine Ass'n., determine the current average ponderosa pine lumber selling value per M board feet. This is the par value of lumber from a grade 5 tree and is 100 percent of the selling value of lumber produced from the timber chance.

4 - Apply standard percentage ratios to lumber selling value per M through all tree grades.

5 - Apply percentages (step 2) of each tree grade to selling values obtained from Step 4. Summarize weight of selling value of each tree grade and you have the average selling value of lumber produced from the stand you have cruised.

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FIG. 2 — TREE GRADES FOR PONDEROSA PINE

GRADE NO.	AGE	LUMBER PRODUCTION	SIZE LIMITS	KEEN CLASS
1 (SELECT)	mature or overmature usually 300 years or older.	ordinarily 20 to 40% D&BTR. select with lesser amounts of shop lumber.	seldom under 20" d.b.h. except on poorest sites.	Invariably 3 and 4 rarely 1 or 2
2 (SHOP)	mature or overmature usually 300 years or older.	ordinarily 25 to 40% of shop lumber all grades - with lesser am'ts of D&BTR.	rarely under 26" d.b.h.	usually 4 sometimes 3
3 (BULL PINE) YOUNG	immature - usually not over 120 years old.	yield 30 to 60% of #2 common lumber	seldom over 18" d.b.h.	usually 1 rarely 2
4 (BULL PINE) OLD	just going into maturity usually not over 250 years.	yield 30 to 80% 3 common & poorer including 3 shop and inch shop.	rarely under 18" d.b.h. and seldom over 30" d.b.h.	usually 2 rarely 1 and 2
5. (MIXED GRADE)	usually mature and overmature and over 250 years.	yields mixture of grades - 3 common & poorer predominate - 1 & 2 common comparatively rare.	seldom under 20" d.b.h. except on poorest sites	usually 3 and 4
6 (INFERIOR)	usually mature or overmature but may be any age.	invariaby 75% 3 common and poorer - frequently all 4 & 5 common.	any size	usually 3 and 4 but may be any class

Table 1. Summary of quality of old-growth timber
Big Pine Creek sale area

Cruise based on 44 plots = 8.8 acres - included 120 trees or 647 logs

Tree Grade	Net volume on 8.8 acres in cruise	Volume per acre net	Percent volume in each tree grade
1	78,940	8,970	41.8
2	3,800	430	2.0
3 None	—	---	---
4	820	90	.4
5	93,920	10,660	49.7
6	11,510	1,310	6.1
Grand Total		21,460	100.0

Average tree - 1575 ft. net = 5.4 16-foot logs per tree
Average log - 292 ft. net = 3.4 16-foot logs per M

Table 2. Summary of quality of young timber
Big Pine Creek sale area

Tree Grade	Volume per acre adjusted for 5 percent defect	Percent of volume in each tree grade
1	700	6.1
2	0	.0
3	50	.4
4	8670	75.9
5	1390	12.2
6	610	5.4
Total	11,420	100.0

Basis 26 plots

Table 3. Computation of the selling value of lumber produced from old growth timber on the Big Pine Creek sale area.

Tree Grade	Standard ratio to average selling value (1) %	Selling value of lumber based on current average value of $80 per M (2) $	Volume by tree grades to be cut from plot (3) %	Weighted selling value (4) $
1	135	108.00	41.8	45.14
2	115	92.00	2.0	1.84
3	95	76.00	---	---
4	80	64.00	.4	.26
5	100	80.00 1/	49.7	39.76
6	70	56.00	6.1	3.42
All			100.0	90.42

Table 4. Computation of the selling value of lumber purchased from young timber on the Big Pine Creek sale area.

Tree Grade	Standard ratio to average selling value (1) %	Selling value of lumber based on current average value of $80 per M (2) $	Volume by tree grades to be cut from plot (3) %	Weighted selling value (4) $
1	135	108.00	6.1	6.59
2	115	92.00	0	0
3	95	76.00	.4	.30
4	80	64.00	75.9	48.58
5	100	80.00 1/	12.2	9.76
6	70	56.00	5.4	3.02
All			100.0	68.25

1/ Par value

FIG. 1 — # ECONOMIC TREE GRADES FOR PONDEROSA PINE

NORTHERN ROCKY MOUNTAIN FOREST & RANGE EXPERIMENT STATION MISSOULA, MONTANA.

1 — SELECT TYPE — PRINCIPAL — 20% TO 40% SELECT WITH LESSER AMOUNT OF SHOP

2 — SHOP TYPE — PRINCIPAL — 25% TO 40% SHOP WITH LESSER AM'TS OF D&BTR

3 — YOUNG BULL PINE — LUMBER — 50% TO 80% 2 COMMON

4 — OLDER BULL PINE — LUMBER — 50% TO 80% 3 COMMON & POORER

5 — MIXED GRADE TYPE — GRADES — MOSTLY 3 COMMON & POORER

WOLF TYPE 6 LEANING & DEFECTIVE TYPE — INFERIOR TYPE — PRODUCED — 75% 3 COMMON & POORER IMPORTANT 4 AND 5 COMMON PRODUCER

Furniture Process from Rough Lumber to Finished Product

FRANK DE YOUNG, Rway Furniture Co., R. R. 3, Sheboygan, Wisconsin

LETS TAKE A TRIP through a modern furniture plant. Just how do we go about producing fine furniture that is acceptable to Mr. and Mrs. America?

DESIGN

Top management conveys to the designer directions as to the general type of furniture our plant is to produce. The designer then submits a group of sketches for selection. Top management selects the sketches which they think will have customer appeal and can be produced in our particular plant at a profit. After selection of the sketch, the designer is authorized to make full-size drawings. These full size drawings are then sent to the factory where a sample piece or suite is made. Upon completion of the samples, costs are estimated; and a sales price fixed. Top management and the sales department then review the piece or suite and make a decision as to whether the piece or suite is worthy of a cutting in the plant. Upon acceptance of a piece or suite for production it is sent to the factory for process.

PROCESS

The samples are then reviewed by a committee consisting of the factory manager, superintendent, designer, detailer and biller. This committee's duties are to study the types of woods and veneers to be used and the most economical methods of manufacturing. A new master detail incorporating any authorized changes is now made. Next the master detail is given to the billing department where all items listing length, width, thickness, and type of lumber are recorded on a master material bill.

The master detail now goes to the drafting department where prints are made of each individual part. These prints are then sent to the routing department where a listing is made as to the various movements of each piece from the cut-off saw to the cabinet departments.

These prints, along with the routing instructions, are then sent to the time study department where standard piece rates are applied to the routing sheet. Those piece rates not standard will be set by time study upon processing in the plant. Now we are ready to manufacture furniture. Orders are given to the factory as to the proper time to put this new suite cutting into work. A master billing sheet, along with the individual item drawings with their route of operation and rate sheets fixed to them, are given to the rough mill foreman. This is his signal to proceed with the cutting of the new suite.

Well, you can't begin to cut a new suite without lumber so let's go back to the yard.

RECEIVING AND STORING LUMBER

At our Rway Plant we have what is known to us as Building No. 12. This building is 552 feet long and 110 feet wide. The two sides and monitor section are ventilated by open louvers. The lowest part of this building is 25 feet high.

Our incoming lumber is unloaded directly from railroad cars inside the building, and in stickered packages about 50 inches high. A fork-lift truck transfers the package to its proper location within a numbered bay. Timbers are placed under each stack for the fork-lift operation.

In charge of the four lumber handlers and the fork-lift operatior, we have our working yard foreman who scales and grades the lumber. An average of 20 to 25 thousand board feet of lumber is handled each day.

To properly pile our lumber, we have a home-made sticker piling rack. This rack is mounted on wheels and placed parallel to the car being unloaded. Channel irons, properly spaced, are bolted to the side.

A question might be brought up as to the possible savings outdoor storage vs. indoor storage. We do know that when our lumber was piled on kiln cars open to the elements we found the top layers to be cupped, checked, and warped. End checks were also deeper.

Other advantages are than our yard crew can continue to unload cars when weather is bad. Demurrage and our need for finding other work to keep the men occupied is held to a minimum. The entire building has a concrete floor thus

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insuring fast fork-lift operation. There is no removing of lumber from snow banks.

KILN DRYING

We have two large kilns within the lumber storage building and a battery of ten kilns adjacent to our dry storage and rough mill. The total capacity of these kilns is over 200,000 bd. ft.

All of our kilns are automatically controlled with individual reversible fans. One kiln operator is in charge of the proper drying of the lumber. From our kilns our lumber passes into our dry-storage area. This area along with the entire plant is kept humidified as nearly as possible to provide an equilibrium moisture content of between 5 and 6 percent. However, during the summer months the equilibrium goes much higher than 6 percent. After a couple of days of dry storage, the lumber is removed from the kiln cars, passed through a roughing planer, dead piled upon another kiln car and stored until the rough millforemancalls for the particular kind of lumber required at the cut-off saws.

THE ROUGH MILL

This lumber is brought to the rough mill on power-driven transfer cars; some hand pushing is required on certain cross-over areas. Our engineers hope to find some economical method to eliminate the hand pushing.

Upon entering the cut-off saw area, the operator pushes a button to level the lumber lift with the floor. Another button is pushed to move the transfer car on to the lift. Then another button is pushed to lower the lumber to its proper height. At this point the electric eyes constantly maintain the lumber at the proper working height for the cutters.

We have a battery of four semi-automatic type cut-off saws, all operated by a touch of the toe. You will remember that we mentioned the rough planing operation. Our findings are that it greatly helps the cutters to see the defects in the lumber clearly and thus do a better job of cutting.

We know that there are arguments for and against the rough planing idea. We, however, think that our way is the best; taking into consideration the type of furniture we make. Another reason in our favor is that we have a minimum amount of cupped or warped boards thanks to our lumber storage building, proper stacking, and up-to-date kilns. From our cut-off saws, the lumber is passed on a conveyor to a sorter who piles the various lengths on separate trucks. In our old cutting room layout, we passed the lumber directly from the cut-off saw upon a conveyor to the rip saws.

In our present layout, we pile the lumber on trucks. Our reasons for the change are as follows: Formerly when the cutters were having an easy bunk of lumber to cut they would overload the rippers and thus would have to slow up. At other times the cutters would work as fast as possible, and the rippers would have an easy time of it. Our present method of piling to trucks creates a bank of trucks for the rippers. We have a battery of four up-to-date rip saws and one gang rip saw. All of these saws are equipped with counters. The operators and helpers are paid on the basis of the length ripped.

From our rippers the core stock is passed on to what we call a lay-up operation. Here the boards are loosely laid and ripped to a given overall width. After this sizing operation, the lumber goes to the glue-up operation. We believe that we now have a most efficient one-man-operated high frequency core-gluing machine.

This machine was designed by our Rway engineers. This one-man machine is the result of experience. Our previous machine was not too successful from an overall cost angle. For instance, the old machine had two high frequency tubes each at a cost of $300.00. These tubes were guaranteed for 1,000 hours each. They did not last 1,000 hours. On the basis of this experience, we were sure that our tube costs alone were 60 cents per operating hour. Our present machine has but one tube at a cost of $500.00. This tube is still in operation, and the cost is down to less than 15 cents per operating hour. Along with this saving, the machine has also been greatly improved so that one man places the lumber upon a conveyor belt where it is automatically glued, layed up in panel size and pushed into the machine; the finished panels come out beside the operator where they are placed on a truck.

Our core panels are placed within a properly ventilated and humidified conditioning room for not less than 48 hours. Preliminary tests of moisture samples indicated that further drying of glue lines on a high frequency resin cured panel was unnecessary. However, production runs proved that some uneven surfaces could be traced to improperly dried glue lines. We now cure the panels in our drying room. I have in my office some 50 table tops made up with various types of core lumber, some with selected edge-grain, some with alternate edge and flat grain, some with alternate edge and flat grained. Some of these panels were made with animal glue while others are resin glued. Some were sent to the conditioning room, others were not.

Photographs were taken of all of the cores and the cross banding veneers. These panels were

made some six months ago -- properly sanded, finished, and rubbed. Once a month they are inspected for such defects as sunken joints, raised boards, and defective cores cross banding. A record is being kept of these panels, and we do hope that shortly after the first of the year to have some answers as to what procedure to follow in the making of high-quality stock.

I am sorry to say that we do not have in this group any panels with a 1/10 inch tempered masonite cross band. We feel that this might have merit in that the masonite is bound to be more uniform than cross banding which has its hard and soft spots to show themselves through a highly polished table top. Other lumber than that used for cores goes through various other operations such as planers moulders, etc.

VENEER DEPARTMENT

We now come to the veneer department. Purchased face veneers and cross banding are processed through the clippers, redrier, veneer jointer, tapeless splicing machines, and on to the inspectors. Our inspectors check all glued up face veneer sheets throwing out, patching, or taping, whenever necessary.

We now group the proper cores, crossbanding and face veneers at the resin-glue machine. The cross bands are passed through the resin-glue spreader which is properly adjusted to produce the desired even spread of resin glue. The stacker than places these glued cross bands along with face veneer, back veneer, and the core upon a roller conveyor. When the proper amount of panel material for a press load is at hand, the pile is pushed along to the press operator and his helper. The press operator checks the size so as to determine the proper press pressure and the time required for the cure.

Our ten-opening hot press is then loaded, a button pressed, and the press is closed. An automatic timer on the press releases the pressure and the operators unload the press ready for the next charge. Along with this hot press, we also have a cold press. Here we glue up our non-standard sweep or serpentine drawer fronts, blocks, etc. After pressure is applied, retainer clamps are applied so that the stock will be kept under pressure until the resin glue is properly set. You will remember my mentioning the non-standard sweep and serpentine stock at the cold press. We also have a high frequency veneer press. All of our so called standard sweeps are made up with laminations of 1/8 inch rotary cut veneers along with the crossbands, face and back veneers.

Sometime ago we analyzed our costs as to which is the better and most economical way of making up these curved surfaces. Our findings were than there was a slight saving in the use of the laminated stock, as against the lumber block which has to be band sawed and veneer-glued in the cold press. We also find that if the form is properly made, our bent surfaces are much more uniform than in the past.

Let's leave the veneer department and go into our machine department, often called the finish mill.

THE FINISH MILL

This department is equipped with what we think is the best in woodworking machinery, such as automatic shapers, multiple automatic or semi-automatic boring and cut-off machines.

If we can not find the proper kind of equipment for some special operations, we bring the problem to our staff of Rway Engineers. They study the problem and usually come through with an answer.

Our engineering department also supplies the machine department with boring templates and checking gauges. These templates are used in the set-up of the boring machines. After a part has been bored, the machine is again checked with the template.

A question is often asked as to how close do you hold your dimensional tolerances in the plant.

I could tell you that we hold them to less than 1/32 of an inch. One thirty second of an inch would be intolerable if, let's say, it left a chair joint open to that extent.

At another time you could measure the overall length of a credenza buffet and might find the overall length to be 1/8 inch longer than specified. Let's find out why.

A credenza buffet has two outside and two inside ends which are planed to, let's say, a plus .005 of an inch, 4 x .005 = .020 inch. Then we have 16 layers of veneer on these four ends. Sixteen times a plus of .004 inch equals .064 thousandths. Then we have three lengths of partition frames and each is .015 inch plus. Add these all up and you have a plus of about 1/8 inch.

Now let's make the base separately. We could find it to be 1/32 inch shorter than the print. We are then in trouble since the base won't fit the case.

You can understand that we do have problems and often find that two separate sections, such

as the base and the case require us to machine some pieces to fit others.

Now let's check to see what we have, and do, in our sanding department. Here again we have what we think is the best in the way of equipment.

All of our stock is rough sanded at the edger or belt sanding machines with either 2-0 or 3-0 sand paper. Following this operation, all of the stock is sponged so as to raise bruises and the grain. After the stock has been thoroughly dried, a final sanding operation is given with grits anywhere from 3-0 up to 6-0, depending upon the type of stock or veneer being sanded.

Following the sanding operation some of the stock is sent to what we call our preliminary department. Here mouldings, carvings, etc., are applied to the surfaces.

In this department we have a battery of Rway banding machines. These machines are used in the banding of veneers to the edges of tops, partition frames, etc. Resin glue is used in the bonding of these veneers. Our first machine used a steam chest to set the glue line. These steam chests were expensive. Today we have resistance-heated, rubber-covered strips which can be applied to a wooden form. It took some research work on the part of our New York chemical engineer to find the proper type of rubber which would stand up under the heat. The answer was found and today we just ask for a certain length and width of metal-and-rubber bonded strip, and our New York office supplies us with it. Our pattern maker then makes the form, and we are ready to edge band a new top, frame, or any edge-banded contour.

Following the preliminary department we have a thorough inspection of all parts. Rejected parts can often be repaired more cheaply than new ones can be made up. These parts are then sent to our cabinet repair department where they are put back into usable condition. I might tell you that all previous operators are cautioned to throw out pieces that do not warrant further machining operations. Our billing department is on the watch when additional stock is called for to complete a cutting. Through their experience they call for various amounts of overrun when making up the cutting sheets for the rough mill.

Our stock is now machined, sanded, and inspected ready for the final assembly department.

FINAL ASSEMBLY

Our assembly departments are divided into four separate sections, namely the chair cabinet, table cabinet, bed cabinet, and case cabinet.

The case cabinet department is the largest of the group. In this department we have the end, drawer, and case assemblers. From the case assemblers we have a group of men who add certain parts or sections such as the base or deck to the case.

Following this operation, the case is put upon the cabinet conveyor. The first operation is the selection of prenumbered matched sets of drawers and doors which are put into the case. The next operation is the fitting of drawers and doors which is done on specially built edge-sanding machines. Then follow in order the removal of glue from the drawers and softening of edges, the hanging of doors, the placement of drawer guides and stop blocks for the drawers, and the installation of the case backs.

The cases now travel to the rough inspection station. This inspector checks for improperly operating drawers, a loose hinge or some operation that could not be done due to the speed of the conveyor. The repair cases pass on to the repair operators while the others go to the hand sanders. These hand sanders thoroughly go over the entire case picking glue and sanding the entire case with fine sandpaper. Another inspector now inspects the case and, if approved, it is passed into what is known as white stock. Our chair, table, and bed cabinet departments also have their final inspections before passing into the white-stock area.

This now completes what is known to us as the wood shop.

FINISHING

Our finishing foreman receives his finishing orders from the main office. It is seldom that we finish an entire cutting of white stock; we must hold some of the white stock so that we have stock on hand for customer specials. Our type of furniture requires that we cater to special tastes.

We have in our finishing department five separate powered conveyors.

The main conveyor is an overhead type and carries about 80 percent of our finishing production. The other four conveyors are of the platform type. One of these last four is used for bleaching purposes only; another is used for painted furniture; another is used for special furniture; and the last is used for tables.

Our finishes vary from suite to suite. Planning by the foreman must be done with great care so that the desired finish is a direct result of having the right help and materials at the proper stations at a given time.

FURNITURE PROCESS FROM ROUGH LUMBER TO FINISHED PRODUCT

Our cabinet production produces a continuous flow of a certain number whereas the finishing department finishes the furniture by suites. Placement of this furniture must be balanced by having the larger and smaller pieces equally distributed so that all work on the conveyor is well balanced.

All of our lacquers are delivered to the various spray booths through a piping system from a central distributing station.

After the complete finishing cycle, the furniture is transferred directly from the finishing conveyor over to the transportation converyor. This transportation conveyor carries the furniture to our warehouse buildings.

Orders from the shipping department are given to the warehouse as to which pieces are to be moved from the warehouse via the transportation conveyor to our rubbing department. At the rubbing department the furniture is transferred from the transportation conveyor over to the rubbing conveyor.

The first operation is a machine rubbing of the tops, ends, and drawer fronts. Following the machine rubbing, the furniture is taken to our hand rubbers where effort and care is given so that the entire piece is thoroughly hand rubbed. The hand rubbers now transfer the rubbed pieces back to the conveyor. The next operation is the sanding and waxing of all drawer and cupboard interiors. Following this, the piece is well-cleaned and then given a good coat of Rway wax.

The next station is that of inspection where the entire piece is looked over for faulty workmanship. Following this, we come to the trimmers station. All drawer hardware, jewel trays, etc., are assembled at this station. Ornamental hardware and setting of glass in doors is taken care of by our on-the-floor bench trimmers.

Our shipping department issues orders to the warehouse as to which pieces are required for shipment. These pieces are again placed upon the transportation conveyor and removed to the shipping department. Each piece is thoroughly examined and touched-up by our patcher inspectors. Following this, the pieces are regrouped as per customers' orders and again given an overall grouped inspection, being sure that the color, operation of drawers, doors, etc., are up to our quality standards.

Following this final inspection, the furniture is placed within designated truck loading areas.

DISTRIBUTION

The bulk of our furniture is transported by Rway's fleet of diesel-powered trucks. The furniture is delivered to either the dealer or direct to the customer's home. It is a rare occasion that we must crate a suite of furniture to be delivered to some distant place.

All of our furniture is sold by Rway authorized furniture dealers. The dealers, however, do not stock the furniture but bring or send their customers to our factory-operated showfloors where each suite is tastefully displayed in individually decorated room settings. We have fifteen showfloors in operation.

In closing I'd like to sum up what I believe is responsible for the success of our Rway operation.

Rway is the trademarked name of our company. Formerly we were known as the Northern Furniture Company. Rway means the Reiss Way, and we at our plant have a healthy belief that the Reiss way is the right way.

Rway is associated with the Reiss Manufacturing Corporation. Through this association, we have the full benefit of our associated company, with its consulting engineering division complete with research laboratories, chemical, electrical, and mechanical engineers, and machine department.

We at the plant are, as a whole, are an organization staffed with people who have devoted their whole lives to the making of fine furniture.

We believe that with a fine spirit of cooperation as now exists within our entire organization, we can continue to give style, value, and quality far in excess of the price.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Application of Hardboard in Veneered Panels

ROBERT M. BOEHM, Director of Research, Masonite Corp., Laurel, Mississippi

IN RECENT YEARS there has been considerable increase in the use of hardboards in furniture manufacture and in related industries. Of the many, and varied applications which fabricators have developed, the use of hardboards in veneered panels is of particular interest. This application has now reached such proportions and the interest is so widespread that a report on the use of Masonite hardboards in veneered panels is timely. We believe that these developments will in time be generally recognized as marking a significant advance in improved furniture construction.

Two basic combinations of hardboard and veneer, and results of tests made to determine their utility are considered. The first of these is the use of hardboard cross banding, in which the hardboard is laminated between a lumber core and the surface veneer of a thick furniture panel. Cross-sections of typical 5-ply furniture panels using lumber cores are shown in Fig. 1. The second is the use of hardboard as the core in a 3-ply veneered panel for furniture backs, sides, drawer bottoms, etc. The 3-ply construction is shown in Fig. 2.

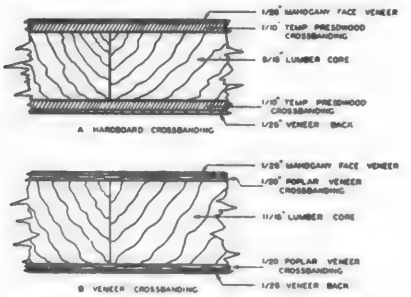

Fig. 1.—Typical cross-sectional views of furniture top panels, comparing veneer with hardboard crossbanding.

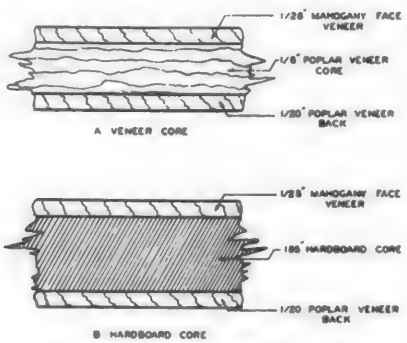

Fig. 2.—Typical cross-sectional views of 3-ply veneered panels, comparing veneer and hardboard cores.

It is not difficult to describe an ideal material for cross banding and cores in plywood. From the production standpoint it should be of uniform thickness, it should not break in handling, and it should be available in large sheets to eliminate all edge gluing. From the standpoint of use requirements, it should be permanently smooth, free of surface irregularities that might show through the face veneer, and it should be of uniform strength, density and hardness. Its expansion with moisture increase should be negligible, and it should repel moisture. It should have substantially the same properties in all directions. It should have good gluing properties and provide a firm foundation for veneer. If its cost per square foot should exceed the cost of veneer, its initial cost should be counterbalanced by economies in the labor cost of fabrication and other savings which accompany its use. It is because hardboards closely approach these ideal requirements that their use is expanding.

As a matter of fact, the whole process of hardboard manufacture is designed to achieve hardness, smoothness, dimensional stability, water resistance, and uniformity of physical properties. The grain pattern of wood has been removed, and wood fibers are reassembled in a heterogeneous mass. Weight, thickness and density are controlled within close tolerances.

While there are several kinds of hardboards on the market today, only two types are available in quantity. The first type, which may be described as the "raw fiber" hardboard, is made by first fiberizing the wood in attrition mills or similar equipment. The fiber is usually felted into a wet mat on a screen from a water slurry, and the mat is then dried under pressure and heat in multiple-opening presses. This type of board is held together with a paper-type bond, which tends to lose its strength when wet. Like paper, these panels may be given a degree of moisture resistance and improved wet strength by the addition of various sizing agents and resins.

The second type of hardboard is made by the process inbented by William H. Mason in the middle twenties. Its manufacture is based upon the use of the Masonite explosion process. In

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annual production, hardboard produced by this process exceeds that of all other process added together. In order to explain the Masonite process it is necessary to point out that wood is made up of three principal components--lignin, cellulose, and hemicellulose or wood sugars. The cellulose is held together by the powerful binding action of lignin. The wood sugars serve no useful function from the standpoint of desirable physical properties. Though any lignocellulose material may be used in the Masonite process, at the present time wood is used exclusively. Cordwood is reduced to chips and fed into large-bore, high-pressure cylinders called "guns". In the gun the chips are subjected to a carefully controlled cycle of steam pressure, directly injected. At the end of the cycle when the pressure is about 1,000 p.s.i. the gun contents are suddenly released or "exploded" through a quick-opening, hydraulically operated valve. Two different actions take place in this operation. First, under the influence of high steam pressure, moisture, and high temperature, the wood undergoes a hydrolytic reaction which breaks down the lignocellulose bond. More specifically, a portion of the lignin is activated and made available for bonding when subsequently subjected to heat, pressure and moisture under proper conditions. Secondly, the sudden release of the hydrolyzed chips to atmospheric pressure tears them apart to produce a characteristically brown, fluffy fiber.

After refining, and washing out of a major part of the hemicellulose fraction, the fibers are deposited or "felted" on the screen of a Fourdrinier-type machine. The resultant thick mat is passed to multiple-opening, steam-heated presses for drying, densification and conversion to hardboards. Under the influence of the pressure and temperature of the press, the lignocellulose bond is reconstituted, so that the board product is really a reconstructed wood, exhibiting the water resistance and wet strength of wood without addition of resins, a feature unique to the Masonite process.

Two important modifications to the above processes should be mentioned. Both methods described are referred to as "wet" process, because the fiber mat enters the press while still wet. The hardboard has the familiar screen impression on its back. Instead of passing the wet mat through a hot press, it may be dried in an oven before entering the press. In that case, press ventilation is not necessary and the press platens are all smooth. The resulting hardboard is therefore smooth on both sides, and is said to be made by the "dry" process. This represented the first modification.

The second modification is achieved by impregnating the pressed panels, of either type, in a resinous solution and then baking. The resultant "tempered" boards have improved water and alkali resistance, and increased strength and abrasion resistance.

HARDBOARD CROSS BANDING

What do hardboards show in the way of advantages when used for cross-banding? The most striking improvement related to surface quality. A standard 5-ply furniture top panel was made up to show the typical surface quality problems encountered when using standard 1/20-inch poplar cross banding under mahogany face veneer. This panel had an edge glued lumber core, and was finished with black lacquer to accentuate light reflection. The panel was examined after conditioning at 30 percent relative humidity. The core was purposely made of low-grade lumber, with open and solid knots, and with three drilled holes 1/2 inch, 3/4 inch and 1 inch in diameter. Several surface defects were apparent in the veneer-cross-banded panel. The sunken glue lines at the joints of the edge glued lumber in the core were quite prominent. The surface distortions at both solid and open knots were very noticeable. Both 3/4-inch and 1-inch drilled holes in the core "telegraphed" through to the surface. The 1/2 inch hole was faintly discernible. The pattern of the cross-banding could also be seen.

A similar panel, with 1/10 inch planed tempered Presdwood cross-banding, was also made. This panel was glued and prepared under identical conditions as the veneer-crossbanded panel just described. Here also, a low-grade core with open and solid knots and drilled holes was used. The hardboard-crossbanded panel, however, showed no sunken glue lines; no mirroring of knots, holes or other core defects; and, of course, no cross banding wood grain pattern.

Figs. 3 and 4 illustrate the type of surface improvement obtainable with hardboard cross-banding. Fig. 3 is a photograph of the surface of a 1/20-inch veneer cross-banded panel, finished by a commercial furniture manufacturer. The photograph was made by reflecting a diagonal light grid on the panel surface to bring out surface irregularities. Three holes 1/2 inch, 3/4 inch and 1 inch in diameter were drilled near one end of the core. These holes have "telegraphed" through to the surface as shown in Fig. 3. This photograph also shows the cross-grain pattern of the veneer cross-banding. In contrast, Fig. 4 is a photograph of a similar panel made under identical conditions, except that 1/10 inch planed Tempered Presdwood was used for cross-banding rather than the veneer. This hardboard cross-banded panel of Fig. 4 shows no "telegraphing" of the drilled holes in the core, and no cross banding wood grain pattern.

While the improved surface quality obtainable with hardboard cross-banding is important in itself, the use of hardboard also makes possible important manufacturing economies. The ability of hardboards to bridge core defects makes it possible to use lumber one or two grades lower than is normally used. As the hardboard cross-banding is thicker than veneer the lumber core may be thinner. Some economy in the use of lumber is thereby obtained. The finished panel is therefore not only better but is comparable in cost to the conventional panel made of veneer cross-banding, notwithstanding the lower unit cost of the veneer.

Manufacturing procedures of core preparation vary among fabricators, and depend also on the end use of the panel. Most manufacturers edge glue the core stock, and age the same for periods of from one day to a week, before final planing. There is a possibility that hardboard cross-banding will render the edge gluing and subsequent seasoning and replaning of the assembled core unnecessary. This procedure is to be developed and tested in factory operations.

A series of tests were run to determine the resistance of the two types of furniture tops to surface damage. The test consisted of pressing endwise a short piece of drill rod 1/16 inch in diameter into the panel surface, and measuring the load in pounds and the depth of penetration. The results of this test are illustrated in Fig. 5.

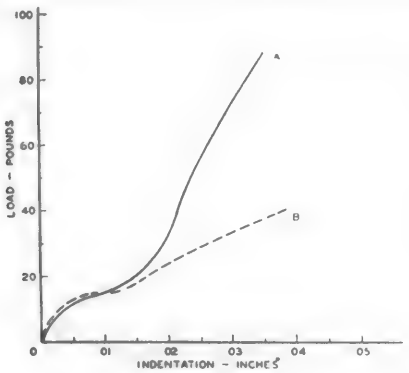


Fig. 5.—Surface indentation of hardboard cross-banded table top compared with veneer cross-banded table top. Curve (A): 1/28" mahogany face veneer, 1/10" planed Tempered Presdwood cross-banding and 3/4" poplar lumber core. Curve (B): 1/28" mahogany face veneer, 1/10" poplar veneer cross-banding and 3/4" poplar lumber core. Indentation measured for indicated load on a 1/4" diameter steel rod pressed endwise into the panel surface.

At penetrations up to about .01 inch, resistance to damage is apparently a function of the surface veneer only. As the load, or damaging force, increases beyond this point, however, the type of cross-banding begins to have effect. For example, at a 40-pound load the steel rod penetrated the surface of a standard, veneer cross-banded table top to a depth of .038 inch. By substituting the 1/10-inch hardboard for the veneer cross band, the penetration was reduced to .022 inch.

A feature of hardboard cross-banding which should not be overlooked is the greater surface smoothness obtained. Smooth panels require less sanding. To these advantages may be added greater ease of handling hardboard in comparison with veneer, less breakage and waste, and elimination of splicing of cross-banding veneer.

Some people may regard the increased weight of hardboard cross-banding in furniture panels as a disadvantage. A hardboard-cross-banded furniture top will weigh about one-half pound more per square foot than an equally thick panel made with veneer cross-bands. Other people may, however, regard the increased weight as an asset indicating massive and strong construction.

HARDBOARD FOR 3-PLY PANEL CORES

The second major application of hardboard is as a core material in 3-ply veneered panels. Such panels are used in the manufacture of furniture for end panels, drawer bottoms, back panels, drawer dividers, mirror backs, and in fact for every type of application where 3-ply plywood is used. Though more experience and test data have been developed for the 3-ply construction, 2-ply panels, with veneer on one face of the hardboard only, are also finding application. Data on the manufacture and use of 2-ply veneered hardboard panels are, however, not yet sufficiently developed to justify publication at this time.

In tests made in the Masonite laboratory on hardboard as a core material, a hardboard 0.185-inch thick was selected, so that when laminated with a 1/28-inch face beneer and 1/20-inch backveneer, it would yield a 3-ply panel about 0.270 inch thick. The panel, when sanded has a nominal 1/4 inch thickness. While all test data were developed with this thickness, it should be noted that an important advantage of hardboards is the large variety of thickness, densities and physical properties available. For example, Masonite hardboard suitable for cores ranges from 1/10 inch to 1/4 inch in thickness. Thus, the fabricator, through proper selection of his hardboard core and veneer thickness, is able to produce veneered panels to suit each requirement.

For comparison, tests were also run on 3/16-inch, 3-ply plywood. To provide an additional comparison of hardboard and veneer as a core material, plywood panels were also made using a poplar veneer core of the same thickness as the hardboard. All test panels were made from selected veneer stock, preconditioned, glued and seasoned under identical conditions. Table 1 shows the construction of the three panels.

TABLE 1.—CONSTRUCTION AND LAMINATING PROCEDURE OF VENEERED PANELS OF TABLE 2

Panel	A	B	C
Type Core	Hardboard	Poplar Veneer	Poplar Veneer
Core Thickness, Inches	0.185	1/8	0.185
Type Face Veneer	Mahogany	Mahogany	Mahogany
Face Veneer Thickness, Inches	1/28	1/28	1/28
Type Back Veneer	Poplar	Poplar	Poplar
Back Veneer Thickness	1/20	1/20	1/20
Finished Panel Thickness, Inches	.275	.210	.275
Finished Panel Weight, lb./sq. ft.	1.16	0.57	0.76
Type Glue	Urea Formaldehyde	U-F	U-F
Glue Extension, % Wheat Flour	50	50	50
Pressing Method	Hot	Hot	Hot
Platen Temperature, °F	240	240	240
Pressure, lb./sq. ft.	200	200	200
Press Time, Minutes	3	3	3
Preconditioning	Room	Room	Room
Seasoning, Days	7	7	7
Method of Stacking	Solid	Solid	Solid

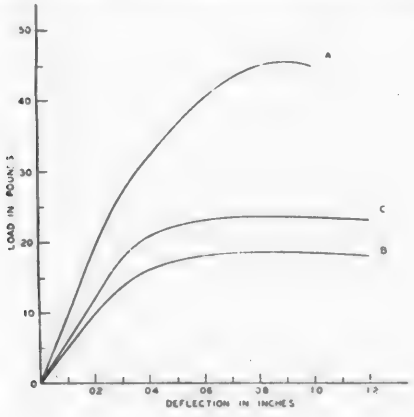
Six 24-inch by 24-inch panels of each of the three types of Table 1 were made in the laboratory. A tabulation of the average strengths in transverse bending for some of the tests is given in table 2. The transverse test results

TABLE 2.—TRANSVERSE BENDING TEST RESULTS, 3-PLY VENEERED PANELS

Panel	A	B	C
Core	Hardboard	Poplar	Poplar
Nominal Thickness, Inches	1/4	3/16	1/4
Transverse Breaking Load, Lbs. (1)	43.6	16.5	34.1 (4)
Stiffness, lbs./0.1 in. (2)	8.2	3.5	5.5
Toughness, in.-lbs. (3)	27.4	16.4	23.1

(1) With the surface veneer grain across supports, 10 inch span, sample 1 inch wide, loaded at 0.5-0.7 inches/minute. Check tests made with 3-inch wide Samples gave approximately the same results.
(2) With the surface veneer grain parallel to edges of Supports, same sample size and loading rate as (1). Stiffness reported as pounds 0.1 inch of deflection before the proportional limit.
(3) With the surface veneer grain parallel to edges of supports, size and loading rate as (1). Toughness reported as area under the load-deflection curve to rupture.
(4) This value for breaking load is across the grain. The "with grain" value is 25.5 lbs.

are those obtained in the maximum strength direction, which, with the exception of the 1/4-inch plywood, is "with" the face veneer grain. Stiffness is measured by the load required to bend the panel a given distance, and toughness by the work done to bend the panel up to the maximum load. The area under the load-deflection curves "with" the face beneer grain is shown in Fig. 6. The tests show that the hardboard core panel excels plywood in strength, stiffness and toughness, these properties being compared in the direction of greatest strength.



As an additional check on strength, the laboratory panels were subjected to a puncture test. This test was made by dropping a ten-pound spear with a conical point on the center of 12- by 12-inch panels supported on the edges. The spear was first dropped from a 1/2-inch height, and the height of drop was then increased in 1/2-inch increments until the spear penetrated through the panel. The average maximum heights of drop were 8.0 inches for the 3/16-inch plywood, 9.8 inches for the 1/4-inch plywood, and 8.6 inches for the 1/4 inch panel with the hardboard core. In this test, the hardboard core was somewhat weaker than the veneer core of the same thickness. However, the 3-ply panel with the hardboard core has a resistance to puncture which is sufficient for furniture application, as shown by the comparison with 3/16-inch plywood.

Several tests were run to determine stability and resistance to checking and edge splitting when the panels are exposed to extremes of atmospheric humidity. Permanence of the glue bond and resistance to peeling were also tested. Standard Type-II glue line tests were made on samples from all test panels. This test, described in Douglas Fir Plywood Commercial Standard CS 45-48, par. 14A, interior type, consists of ten cycles of 4 hours submersion in water, followed by 20 hours drying at room conditions. After this ten-cycle test, the samples were inspected for delamination. All panels, with both poplar and hardboard core passed this test.

In addition, samples from each test panel were brought to equilibrium at 90 percent relative humidity, and then oven-dried to constant weight at 130° F. After this treatment, the samples were carefully inspected for face veneer checking, peeling away of the veneer, delamination, splitting, and any other failure of the construction that may have occurred. All panels, both with hardboard and with poplar cores passed this test satisfactorily.

The dry bond strength was tested by inserting a sharp knife blade into the glue lines in an effort to delaminate the panels along the glue line. All panels, both those having hardboard and poplar cores, showed no progressive separation along the glue line.

The final laboratory evaluation tests made were measurements of warp of the 3-ply panels after they were brought to equilibrium at room conditions, and at 30 percent and 90 percent relative humidity. Two warp characteristics of the panels were measured, which we have called "median warp" and "twist". These tests were run on one-foot-square specimens, using three samples for each of the three types of panel.

Fig. 7 illustrates the method used to measure median warp, it being simple the distortion of the panel edge from a straight line, both across and with the face beneer grain. To measure twist, the specimen was placed on a plane surface with the mahogany face veneer up. Three corners of the sample were held in contact with the plane surface, and the distance of the fourth corner to the plane surface was measured.

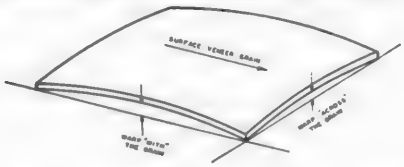


Fig. 7.—Illustration of method used to measure median warp. Duplicate measurements were made on opposite edges. Specimens were 12" x 12" Warp was assigned positive sign if mahogany face veneer was up, and negative sign if poplar back veneer was up. Measurements were made at midpoints of the edges.

Table 3 gives the average results of the tests. These measurements indicate that 3-ply panels with a hardboard core are at least as good as 3-ply plywood in resistance to warp.

It should be pointed out that this warp data is not necessarily reproducible, since each panel has its own "personality" characteristics in this respect, due to the grain pattern of the plies. A hardboard core with its non-grain properties would certainly tend to minimize warpage.

TABLE 3.—WARP OF 12 x 12-INCH, 3-PLY PANELS

Panel	Core	Nom. Thick. (inches)	Avg. Median Warp With Grain (inches)	Avg. Median Warp Across Grain (inches)	Avg. Twist (inches)
Room Conditions					
A	Hardboard	¼	.000	.005	.000
B	Veneer	⅜	.010	.042	.021
C	Veneer	¼	.005	.003	.005
30% Relative Humidity					
A	Hardboard	¼	—.005	.040	[illegible]
B	Veneer	⅜	.031	.109	[illegible]
C	Veneer	¼	.023	.030	.021
90% Relative Humidity					
A	Hardboard	¼	—.041	.016	—.011
B	Veneer	⅜	—.070	—.003	—.109
C	Veneer	¼	—.064	—.016	—.027

Full size 4-by 8-foot 3-ply panels with hardboard cores were laminated in a commercial plywood mill. Excellent quality panels were produced, with a urea-formaldehyde glue extended 100 percent with wheat flour, though the 100 percent extension may not be desirable for some applications. This mill test brought to light a decided advantage of the hardboard core construction. The hardboard core panels were markedly smoother and flatter than comparable plywood panels made under the same conditions. It was observed that the panels required only one pass through the drum sander, as compared to multiple passes for comparable plywood. This is one of the practical advantages accruing from the use of a smooth hardboard of uniform thickness.

Several other production advantages should also be noted. The preparation of the veneer core is completely eliminated. It is not necessary to grade, clip, edge glue and precondition the hardboard core. The hardboard, unless exposed for some time to extremely high or low humidity, contains moisture in the right range for gluing without preconditioning. Handling the hardboard cores, particularly through the glue spreader, is considerably more convenient. The effect of these production features is a simplified process, accompanied by real savings in labor, supervision and material.

On the disadvantage side of the picture, some fabricators may regard the greater weight of the cores as being objectionable. For example, the 3-ply, 1/4 inch hardboard-core panel is about 50 percent heavier than the 1/4-inch plywood. While this will not cause a great increase in the weight of furniture, it will affect the shipping cost of the veneered panel from a plywood mill to the furniture manufacturing plant. On the other hand, some furniture distributors regard a slight increase in weight as an asset indicating greater solidy and strength. Certainly, the increased trend in the use of hardboard cores indicates that the improved quality and manufacturing advantages more than offset the increased weight.

SUMMARY

The reasons behind the trend toward hardboard usage in commercial veneered constructions are thus apparent. In the manufacture of furniture tops, hardboard cross-banding permits simplified manufacturing procedures and savings in material and operation. At the same time, it offers greatly improved quality in surface characteristics, such as knot-hole bridging and virtual elimination of all interior defects. Likewise, use of hardboard cores for 3-ply panels results in improved strength, and reduced warp, without sacrifice of the internal strength characteristics of plywood. Production improvements are also obtained. These advantages are obtained with existing commercial laminating equipment and with presently used glues.

As pointed out, work is in progress on a 2-ply hardboard-veneer panel. Indications are that the problems of distortion from unbalanced construction can be satisfactorily solved for some panel uses such as drawer bottoms and backs of case goods. Some developments of five-ply constructions with hardboard cores are also under way. However, it is believed that thicker 3-ply panels with hardboard cores will eventually be produced to replace the 5-ply panels.

Finally, in a time of shortages and diminishing log supplies of the type that can be converted into veneer, it is encouraging that hardboards can now replace veneers to a large extent, through the utilization of woods not suirable for the manufacture of veneer. This replacement will not sacrifice, but rather will improve quality.

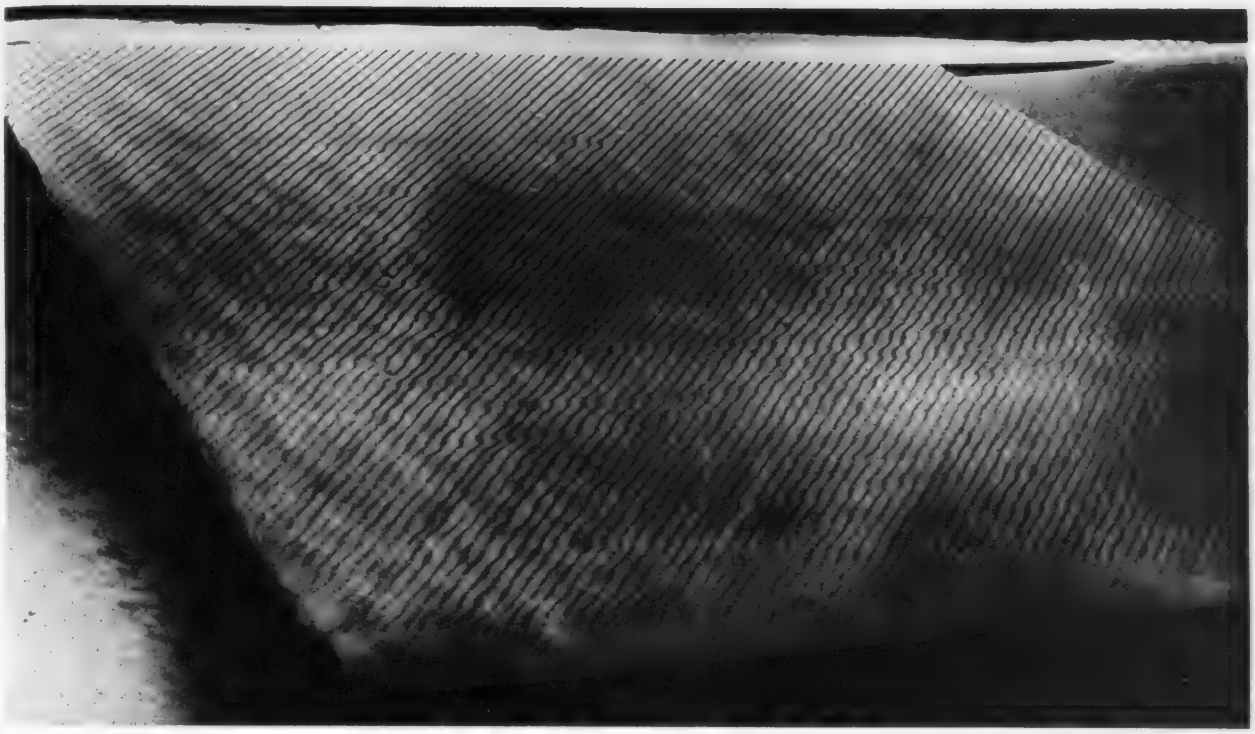


Fig. 3.—Veneer cross-banded furniture top panel, showing typical surface defects: Diagonal lines are reflected from a light grid. Note the three surface distortions near the upper end of the panel caused by holes, 1″, ¾″ and ½″ in diameter, drilled in the lumber core. Note also the "zig-zag" appearance of the grid lines caused by "telegraphing" of the cross-banding veneer wood grain pattern.

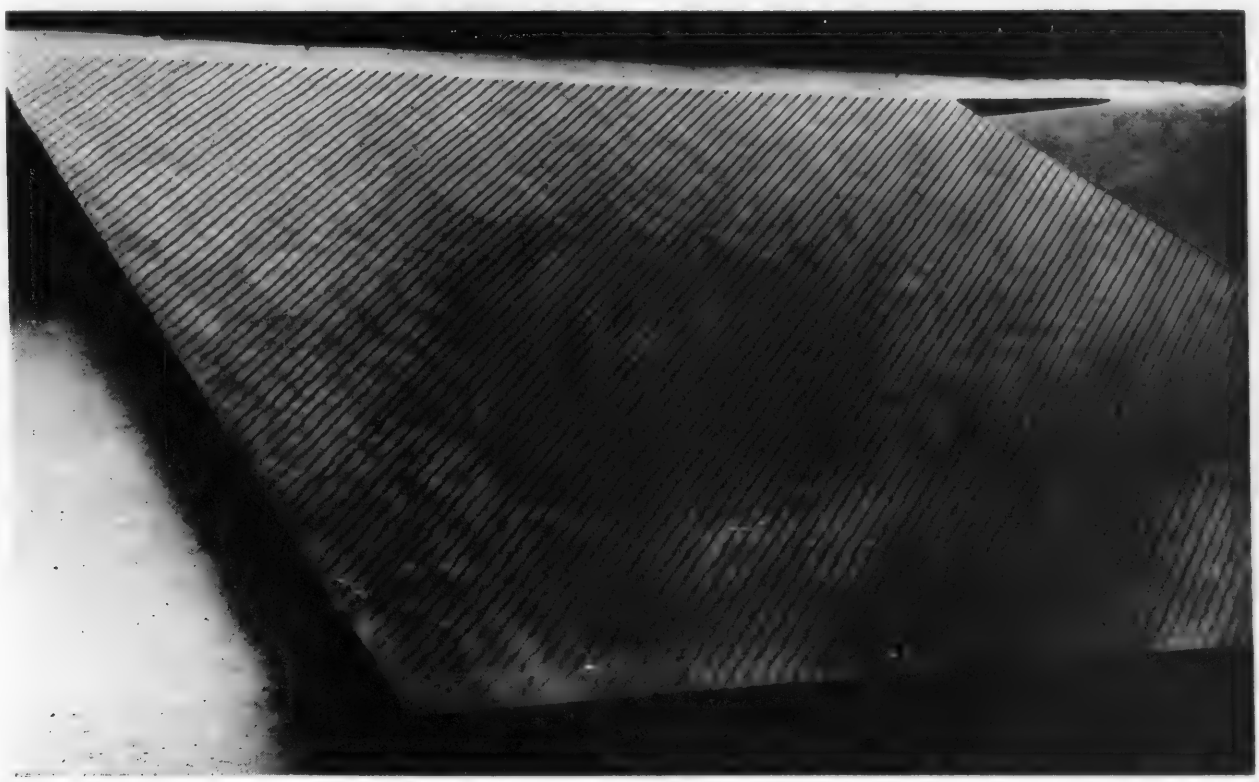


Fig. 4.—Hardboard cross-banded furniture top panel, showing improvement of surface. Compare with Fig. 3. Drilled holes in the core, located in the same position as those of Fig. 3, do not "telegraph" through to the surface. Note also the smooth surface free from any cross-banding wood grain pattern.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Volume Production of Standard Sizes of Veneer

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INTRODUCTION

IN CONSIDERING the title of this paper, it will be helpful for you to bear in mind throughout, that there are certain peculiarities and definite factors and limitations which fit into, and influence the pattern of our production. These factors are controlled to a great extent by the nature of the logs that we are able to obtain, and by the panel size to which we have devoted the full production of our plant. Naturally we have made every effort possible to arrange the physical setup of our plant and equipment to suit these factors, and in doing so, may have made some developments that will be of service and interest only to ourselves. Other developments may be of interest to you. At any rate, we shall be talking only of the production of birch veneer for plywood use in 84-inch lengths.

Early in World War II a singular and very heavy demand developed for high-grade birch veneers of thin and uniform thickness, and in the 6, 7, and 8-ft. lengths. At that time this demand caught the hardwood industry rather flat, with a long history of dimension production behind it, but with little experience in long length veneer production, and with totally inadequate plant facilities and equipment necessary to obtain the required grade and yield from birch logs. This combination of circumstances and the absolute necessity of increasing production, led to a revolution in the plants and layouts of the hardwood industry. New machinery, new methods, and adaptations of existing machinery and methods were quickly developed, and these, to such an extent that the hardwood industry soon had a rate of veneer production and a standard of quality of which they could be justly proud.

As this development continued and production requirements were further increased, the one thought uppermost in the mind of any plant manager was to get the maximum footage and yield of face grade veneer in the longest length possible. Thus, the natural goal became the volume production of a standard size.

Presented at meeting of Midwest Section, Forest Products Research Society, Oshkosh, Wis., September 19-21, 1951.

COOKING

No factor that I know of has as much initial influence on the production rates of long veneer, as the systems that are used to cook or steam logs before they are ready for the cutting lathe. Here again bear in mind that we are speaking only of birch, and that in order to obtain sufficient yearly quantity of this species we are required to take several grades in tree length form. As fast as these logs are received in the log yard, they are placed in water storage or sent directly to the vats before sawing into bolts or lathe length. The purpose of doing this is to eliminate so far as possible the danger of block end checks. Furthermore, our experience has led us to believe that cooking long logs in hot water is the best all-around answer. With a vat holding capacity of 140,000 board feet we are currently following a four-day schedule of cooking. Of these four days, in the summertime the logs are held 2-1/2 to 3 days at 160°, then the temperature is increased the last 1 to 1-1/2 days to 200° or slightly over. In the wintertime, with frozen logs and extreme temperatures, it is necessary to start the temperature rise a day early, with a schedule of two days at 160°, and two days increasing to, and holding 200°. This cooking schedule of the long logs produces a thoroughly saturated, thoroughly heated, and very uniform log to cut. It is ready to be removed from the vats any time that it is required, but it is not taken out more than fifteen or twenty minutes before the lathe is ready to use it. Since this is a tree length log and since it has been cooked in the long length, it is a great deal easier to make the necessary bolts for 84-inch veneer. Most logs come with a 6- or 8-inch trim allowance on each end, so that after sawing there is little sign of block checking. Practically all of these blocks can be run on the lathe to the core without a sign of end checks in the veneer sheet.

To provide this steaming cycle, our system of vats consists of reinforced concrete tanks 20 ft. by 30 ft. by 14 ft. deep. A bridge crane with cross travel head, travels the length of the tanks. Between the two of the middle tanks of the row, a carrier is provided for moving the logs indoors to the log saw, which does the required cutting to block length. To load these tanks, logs are secured in sling chains with approximately one thousand feet of logs to each

sling and these are placed in the empty tanks. As each tank is required for use, water is pumped from it into an adjacent tank which has been recently filled with fresh logs. As soon as the water is removed from the tank, the bridge crane is able to pick up the sling of logs and place it on the saw carrier.

THE ROUNDUP

After the logs are conveyed into the mill and sawed, they are placed directly into a barking or rounduplathe. This roundup lathe is positioned below, but a little in front of, the cutting lathe. The purpose of this machine is to slab off the outside bark and waste and reduce the log as to near the proper size and shape as possible, before it procedes to the cutting lathe. For our requirements we find that we benefit in the use of this machine by a tremendous increase in veneer production with hardly any loss of veneer yield. In fact, it boosts our lathe production to such an extent, that it is almost impossible for the barking lathe to round up the logs as fast as the production lathe can cut them into thin veneer. Another advantage this machines creates is to greatly reduce the labor involved in doing the final cleaning of the log before cutting. In our production, only two men are necessary to do the cleanup work for 30,000 board feet of log cutting.

REELING

As these improvements in the industry continued during the war years, the development of the mechanical reeling system exerted great influence on the eventual overall production. It enabled one to visualize a very high cutting speed, because the veneer could be spooled on the reels at a rate of speed far in excess of the conventional methods of pulling the sheet up a clipper table, or transferring it onto a moving deck as it came from the lathe.

The reeling station could be placed at a convenient height on the outfeed side of the lathe on a track which, after the reel was completed, served as a runway to remove the loaded reel in a single motion. A rack of empty reels was provided just above this track and the reels positioned at the reeling station without lost time by the operators. At one end of this station a mechanical drive was provided, and in order to obtain an easier synchronization of the veneer reel to the log speed, the development of the electric clutch drive was started. This was controlled quickly and efficiently by a small rheostat knob and in the end it was this simple drive that took care of all the requirements of the various tensions necessary in winding different veneer thicknesses in such a satisfactory manner. It fitted in perfectly with the ability of the high speed lathe to get the utmost out of the birch log.

Along with this reeling system the steam engine drive became necessary. Though steam engines had been used by fir producers on the coast for many years, it was new to the hardwood industry but was not required for its power and flexibility. It could start easily in the cut, accelerate rapidly to high speed, and also make quick stops when a plug on the nose bar, or a break at the log occurred. It allowed the lathe operator to move the sheet of veneer slowly to the reeling station, stop the lathe in the cut and then start up slowly when the reel was ready for the veneer. It could then increase its speed to whatever maximum the condition of the log, lathe, or thickness of veneer being cut, would permit. With proper preparation of the log, spindle speeds of 200 rpm. are not unusual with a good lathe.

This arrangement of ample footage of well cooked logs, together with the high spindlerpm. and no loss of time in veneer handling, about tripled normal daily production rates. In fact, as the lathe and its accessories became more and more efficient it was soon apparent that it was taking longer to peel off the roundups from the log than it was to cut the log into veneer form on the reel.

This descrepancy was occasioned primarily by two things. One was the normal trouble in handling irregular sheets of veneer at even a slow rate speed, and the other was, with the veneer reel in its proper position, it was directly in the way of the man trying to reach and handle the roundup. A simple, but very effective answer to this problem can be found by mounting the cutting lathe on the second floor or at a considerable level above the roundup clipper table. In this way the lathe operator rounds up logs at a high rpm. and lets the skirts and irregular sheets slide down a chute in a bunch to the roundup department. As soon then, as the operator has obtained a full length sheet, or one that is in suitable condition to reel, he stops the lathe, breaks the sheet, and starts reeling. While he is reeling the logs into veneer, the men on the roundup clipper table have time to rearrange and lay up the roundup veneers in a conventional manner, sending them on through the bunch clipper. Thus at a normal rate of work they can just about rearrange these roundups, while the operator completes the reeling of the log.

CARE OF THE KNIFE

Another problem arising at the lathe due to a sizeable increase in production, is keeping the veneer knife in satisfactory shape for a full days

production. The fact that nothing but well cooked logs are used, naturally exerts its influence on how long the knife will last, but we have found in regular production that it is best to change the knife twice a day. In order to deal with this problem we have come to the use of knife holders, instead of mounting the knife in the conventional manner on the knife carriage. In using these holders the knife is pre-set in the holder and then ground with a good grinder to a perfectly straight edge. The same arrangement and treatment is also given to the nose bar. When the knife and holder are placed on the lathe, it is only necessary to run in the holding bolts with an air wrench, and the knife is ready to cut since there are no other adjustments available on it. Thus a complete change of knives, that is, taking one off and putting a new one on, can be accomplished in only a few minutes.

IMPROVED HANDLING THROUGH DRIER

As the preparation of the log for the lathe improved, and the ability of the machine to reduce the log to veneer at tremendous rate of production increased, there arose an increasingly difficult problem of how to handle efficiently these large quantities of veneer as fast as they were cut. On the one hand, you had accomplished a big improvement and quality, and had reduced the labor in handling to a minimum. Yet on the other hand, when the reel of green veneer was completed, the veneer operation from then on followed previous patterns. The reels of green veneer were usually sent to a clipper of the semi-automatic type, which single clipped the sheets from each block, cutting them to grade insofar as possible and at as high a rate of speed as possible. It was a choice of maintaining a high conveying speed at the clipper or of providing additional clippers to do the job. If the former choice were made it meant sacrificing clipping accuracy and veneer yield, and if the latter, a sizeable increase in labor and plant space would be required. Whichever choice were made the veneer was conveyed away from the knife and the pieces were placed on a load. The green load was then sent to a conventional drier, where, as the pieces were put through it, and repiled in another load at the outfeed end of the drier, a further mixup in the veneer relationship occurred. The usual procedure after this was to send this load to graders. They would then try to lay up and match these veneers for grain and color, in a face grade, preparatory to sending them to the edge gluers.

All through this process of clipping, drying, and grading a great deal of labor was involved, and obviously, as the material passed through each set of hands a considerable amount of mechanical damage occurred. This meant that in order to carry on the new theme of efficiency in log handling and preparation, and to fit in with the great strides that the cutting lathe had made, a new method of drying, clipping, and veneer grading must be developed.

After a considerable amount of experimentation, a drier was brought into production that permitted a reel of green veneer to be unwound through it, on a moving apron, providing a continuous sheet of dry veneer at the outfeed end. By installing the semi-automatic clipper immediately at the end of the conveying apron, the continuous sheet of dry veneer could then be graded and clipped to excellent advantage. Clipping accuracy was improved to the point where defects less than an inch in width could be removed. Standard widths could be clipped with no unnecessary allowance for shrinkage, and at no point in this process could any mixup occur in the relationship and matching of the adjacent veneers, as they were carried along the clipper outfeed table. In addition to this the drying of the veneer in these continuous sheets greatly improved the over all quality. At last, the reels of veneer could be placed at one end of the dryer and sheets of veneer produced off the outfeed conveyor, graded, dry clipped, and matched before any human handling was necessary. In this way a bolt is reduced from log form to usable dry veneer before it is touched or laid onto a load that has to be moved from one department to another.

It is easy to visualize what an improvement this affords in lack of mechanical damage, and what a saving in labor and plant space was accomplished.

JOINTING AND SPLICING

Since the veneers from this production were intended for plywood consumption, one further step was necessary to put them into final form for plywood gluing. Edge gluing has generally been considered one of the most difficult and wasteful processes connected with finished face production. From the conventional drier previously mentioned, and after all the necessary steps in grading and matching were completed, a further difficulty arose in getting the material up to and through the jointers and edge gluers at a satisfactory rate of production. Also, a great deal of splicing difficulty always arose from poor jointing, usually associated with the crooked edges which develop in the uneven shrinkage of veneers as they are dried in piece form. The standard answer to this problem of crooked edges seemed to have been to reclip

these veneers after drying, thus suffering an additional loss of yield and further mechanical damage. In using this method of loss of yield of some 40 percent was generally anticipated.

With the advent, however, of the reel type of drying, the jointing and splicing department could be tied to the end of the clipper conveyor to eliminate most of these problems. In the first place the veneer is already dry clipped before it moves along this conveyor; secondly, the matching of the adjacent sheets is nearly perfect, and thirdly, production rates are sharply increased since the even flow of veneer at table height, virtually eliminates waste motion. Veneers flowed at table height through the jointers then onto a belt parallel to the splicers and then finally through them. As a result of this arrangement the first and only time that the veneer is placed on a load ready to be moved, is when it is either a finished face or back, one piece or edge glued, ready to be taken to the gluer. All the way through this process of cutting, drying, and splicing the secret of the production rate has lain in the fact than an even flow of material is always maintained. No stops along the way are made before the job is completed. The reels of veneer have moved on a track from the lathe to the drier and the veneer has moved off the reel and through all of these operations without anyone ever having to pick it up or lay it down.

HANDLING END PRODUCTS

At this point, when the veneers are finished, they are placed on a load ready to be moved to the gluer. Pallets and gas driven fork trucks are used for this prupose. The use of these machines has provided a great saving in the ease with which finished loads of veneer and plywood can be moved and furthermore allows piling loads on top of each other, thus about doubling the floor areas available for machine use.

In sending these loads of veneer along to the gluer, provision is always made for hydraulic lifts, to enable the work to be kept at machine level at all times. Veneers just cannot be handled properly, or at any rate of speed, if it is necessary to reach down and pick up sheets of veneer one at a time. By providing lifts, the faces and backs can be kept level and can rapidly be moved sideways as required onto the bunching box where the assemblies are built up in readiness for the hot-plate press. As the plywood comes from the press it can be sawed immediately, and if it is to be shipped unsanded can be baled and loaded by fork truck into the freight car as it develops. If, however, it is to be sanded it is desirable to leave it in a hot stack overnight.

Thus the goal of the standard size, the improvements in machines, layout, and technical knowhow have resulted in the production of standard sizes at such a high rate of speed and in such a manner that a block from a log that goes into the lathe during the forenoon can be loaded into the freight car in plywood form in the afternoon.

JOURNAL of the FOREST PRODUCTS RESEARCH SOCIETY

Effectiveness of Different Conditioning Schedules in Reducing Sunken Joints in Edge Glued Lumber Panels

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Sunken joints are common defects of edge-glued lumber panels. They are caused by surfacing the stock too soon after gluing and possibly also by other factors. The wood adjacent to the joint absorbs water from the glue and swells. If the panel is surfaced before this excess moisture is distributed, more wood is removed along the joints than at intermediate points. Then during subsequent equalization of the moisture, greater shrinkage occurs at the joints than elsewhere, and permanent depressions are formed.

This problem has been well recognized, and for nominal 1-inch panels glued with animal, casein, or starch glues conditioning periods of 5 to 7 days at 70° F. or 2 days at 100° F. have been recommended to reduce difficulties with sunken joints.[1] When using urea-resin glue, that introduces less water than the older types of glues, however, it has been commonly believed that the conditioning period could be greatly reduced, particularly where heat was employed for curing, as in high-frequency gluing.

This report describes procedures used in detecting and illustrating sunken joints and summarizes the information gained on the effectiveness of different conditioning schedules in reducing this type of defect. Both animal and urea-resin glues were used, and the latter, besides being set at room temperature, was also cured by high-frequency dielectric heating and by other heating methods.

MATERIALS AND PROCEDURES

Nominal 1-inch yellow-poplar lumber, conditioned to about 6 percent in moisture content, was used for making edge-glued panels 12 inches wide and about 14 inches long. A number of panels made of oak lumber (also at 6 percent moisture content) were included for comparison. A few panels were made of lumber conditioned to about 12 percent moisture content, since it had been suggested that panels glued at high moisture content and subsequently dried would develop raised joints. Each panel was made of 4 strips, each 3 inches wide. Certain panels were surfaced immediately after gluing, and others after various periods of conditioning at 80°, 120°, 160°, and 200° F. In each case the humidity of the conditioning room was such that a moisture content of 6 percent was maintained in the panels.

The adhesives used were animal glue (mixed 1 part by weight of glue to 2-1/4 parts water) and urea-resin glue (100 parts resin to 65 parts water) both set at room temperature. Some panels were also made with urea resin and cured by high frequency and others by inserting the panels between heated platens. The glue was spread by brush and a sufficient amount was applied to get some squeeze-out when pressure was applied. In each case gluing pressure was applied to the edge of the panel by means of screw clamps. The assembly periods (time between spreading and pressing) were generally about a minute or less. In the high-frequency method, the curing or heating cycle was about 1 minute, at the end of which period the squeezed-out glue was becoming brittle and the joints would develop considerable wood failure when broken immediately, particularly when poplar was used. When the curing was carried out between heated platens, two different heating cycles, 4 minutes and 1 minute, were used at a platen temperature of 350° F. A special jig was constructed to apply gluing pressure to the edges of the panels during the curing between heated platens.

For some of the conditioning periods, usually the longest and the shortest, where there was little doubt that the conditioning time was either adequate or inadequate, only one panel was made with each glue. For the intermediate conditioning periods, however, as many as 3 duplicate panels were made.

After surfacing the poplar panels were given a finish consisting of (1) sealer, (2) interior enamel undercoater, and (3) high-gloss enamel. The oak panels were given a similar finish except that a filler was used instead of a sealer.

When the finish had dried thoroughly, each panel was examined in a semi-dark room with a strong beam of light directed across the face of the panel and perpendicular to the glue lines. Representative panels were photographed to obtain a record of the relationship between sunken joints and conditioning treatment. The lighting facilities used in examining and photographing the panels consisted of a slide projector (for 2 by 2 inch slides) equipped with a 750-watt bulb. The projector was placed about 7 feet from the panel with the source of light in about the same plane or slightly above the face of the panel. This arrangement, which is illustrated in figure 1, made depressions at

1. "Drying and Conditioning of Glued Joints," Forest Products Laboratory Report No. D475, revised August 1948.

Presented at the FPRS Midwest Section Meeting in Oshkosh, Wisconsin, September 13-15, 1951.

the joints and other surface irregularities readily visible and might be a convenient method for examining panels for surface defects on a production basis. A somewhat similar method has been used in the Douglas-fir plywood industry for detecting steam blisters and other defects in the panels at the time they emerge from the drum sander.

DISCUSSION OF RESULTS

In the following discussion depressions or lines of demarkation at the glue lines are generally referred to as sunken joints. For short conditioning periods there was usually little doubt that actual depressions at the joints occurred. At the longer conditioning periods, however, some joints were practically invisible, and it is possible that the slight lines of demarkation at the joints were caused by minute changes in thickness of adjacent pieces rather than shrinkage at the glue line.

The panels shown in Fig. 2 are yellow-poplar glued with urea resin, cured by high-frequency dielectric heating, and with animal glue cured at room temperature. One panel made with each glue was surfaced immediately after the gluing pressure was released, and the other two panels were conditioned for 7 days at 80° F. and 30 percent relative humidity before they were surfaced. The sunken joints were very pronounced in the panels surfaced without conditioning, and some of the joints were also visible when there was a 7-day conditioning period between gluing and surfacing. Intermediate amounts of sunken joints or lines of demarkation were observed in panels conditioned for 1 and 3 days prior to surfacing. In general, there appeared to be no appreciable difference in the conditioning period required for panels glued with animal glue and set at room temperature, and panels glued with urea resin that was cured by high-frequency dielectric heating. Similar panels that were glued with urea resin, cured at room temperature, and surfaced immediately after release of gluing pressure, also showed pronounced sunken joints. The sunken joints were of decreasing magnitude when the panels were conditioned for 1, 3, and 7 days before surfacing. Poplar panels with urea resin and cured by inserting the panels between heated platens showed sunken joints very plainly when conditioned for 3 days (at room temperature) before surfacing, but only faintly when conditioned for 7 days.

In white oak panels that were glued with animal glue, and with urea resin cured either at room temperature, by high frequency, or between heated platens some joints were visible in every panel when the surfacing was done after 3 days of conditioning. With the animal glue, and probably to a lesser extent with the urea, cured between heated platens, they could be noticed after 7 days. There was no significant difference between urea glued oak panels cured at room temperature, and similar panels cured with high frequency. This, in general, was true also for the poplar panels.

Oak and poplar panels in which the glue was cured between heated platens for 1 minute had slightly more pronounced depressions than the panels cured (by the same method) for 4 minutes. The difference, however, was probably not significant, particularly for the 7-day conditioning period.

One oak and one poplar panel that were cured between heated platens were conditioned for 2 weeks before they were surfaced. No sunken joints could be observed in either of these panels.

Panels of both species that were glued at 12 percent moisture content were also surfaced and finished after 0, 1, 3, and 7 days of conditioning. They were then dried for about 3 weeks at 80° F. and 30 percent relative humidity before they were examined. It had been suggested that under these conditions raised glue joints might develop, since the resin-impregnated layer of wood at the joint might not shrink the same amount as the remainder of the panel. As was the case with those glued at 6 percent moisture content, however, these panels also developed sunken joints of increasing magnitude with decreasing conditioning period.

Panels glued with urea-resin glue, that were surfaced immediately after unclamping, or after 1, 2, 4, 6, or 8 days of conditioning at 120° F., showed sunken joints plainly up to 2 days, very faintly after 4 and 6 days, and after 8 days the joints, in general, were practically invisible. Similar conditioning treatment given to panels glued with animal glue also resulted in joints that could be seen plainly after 2 days and very faintly after 6 days of drying.

Panels conditioned at 160° F. showed sunken joints with both animal and urea-resin glue after 8 hours of conditioning. After 16 and 24 hours, however, only traces of some of the joints could be observed. Very slight traces of some of the glue joints could also be seen in panels conditioned for 2 and 4 days at 160° F. There appeared thus to be very little improvement in the appearance of the panels after 24 hours (1 day) of conditioning at this temperature.

When conditioning was done at 200° F. the joints could be observed after 6 hours, but were practically invisible after 16 hours of conditioning. Panels conditioned for 40 hours at this tempera-

ture showed no improvement over those conditioned for 16 hours.

CONCLUSIONS

These investigations provided a basis for the following conclusions:

1. Panels edge-glued with urea-resin glue, as well as with animal glue, will generally develop sunken joints unless they are adequately conditioned prior to surfacing.

2. Sunken joints were still faintly visible in both yellow poplar and white oak panels, glued with animal glue, when the surfacing was done after 7 days of conditioning at 80° F.

3. With urea-resin glue, sunken joints were consistently visible after 3 days of conditioning (at room temperature) and sometimes faintly visible after 7 days.

4. There was no significant difference, with respect to sunken joints, in urea glue joints cured at room temperature, with high frequency, or between heated platens.

5. There appeared to be no appreciable difference between the period of room temperature conditioning (80° F.) required for white oak and that for yellow-poplar.

6. The required conditioning period decreased with increased temperature. Thus, about the same obliteration of the joints was obtained with the following conditioning treatments:

7 days at 80° F. and 30 percent relative humidity
4 days at 120° F. and 35 percent relative humidity
24 hours at 160° F. and 44 percent relative humidity
16 hours at 200 ° F. and 55 percent relative humidity

These conclusions are based on the appearance of edge-glued panels with a high-gloss finish. The amount of surface depressions that are noticeable with a matte finish, or in panels subsequently covered with veneer, was not investigated.

RECOMMENDATIONS

The conditioning schedules given above are suggested for edge-glued panels that will be used with a high-gloss finish and without veneering. If there is an appreciable layover period between the surfacing and the sanding and finishing operations, the conditioning period can probably be somewhat shortened, since surface irregularities of certain magnitudes are usually removed by the sanding.

For edge-glued furniture panels that are subsequently covered with crossbands (usually 1/16 or 1/20 inch) and face veneers (usually 1/28 inch), it is expected that the conditioning times shown above can be shortened at the different temperatures, perhaps to as much as one-half the periods.

Figure 1.--Method for detecting sunken joints and similar surface defects in panels. The light source is a 750-watt 2- by 2-inch slide projector.

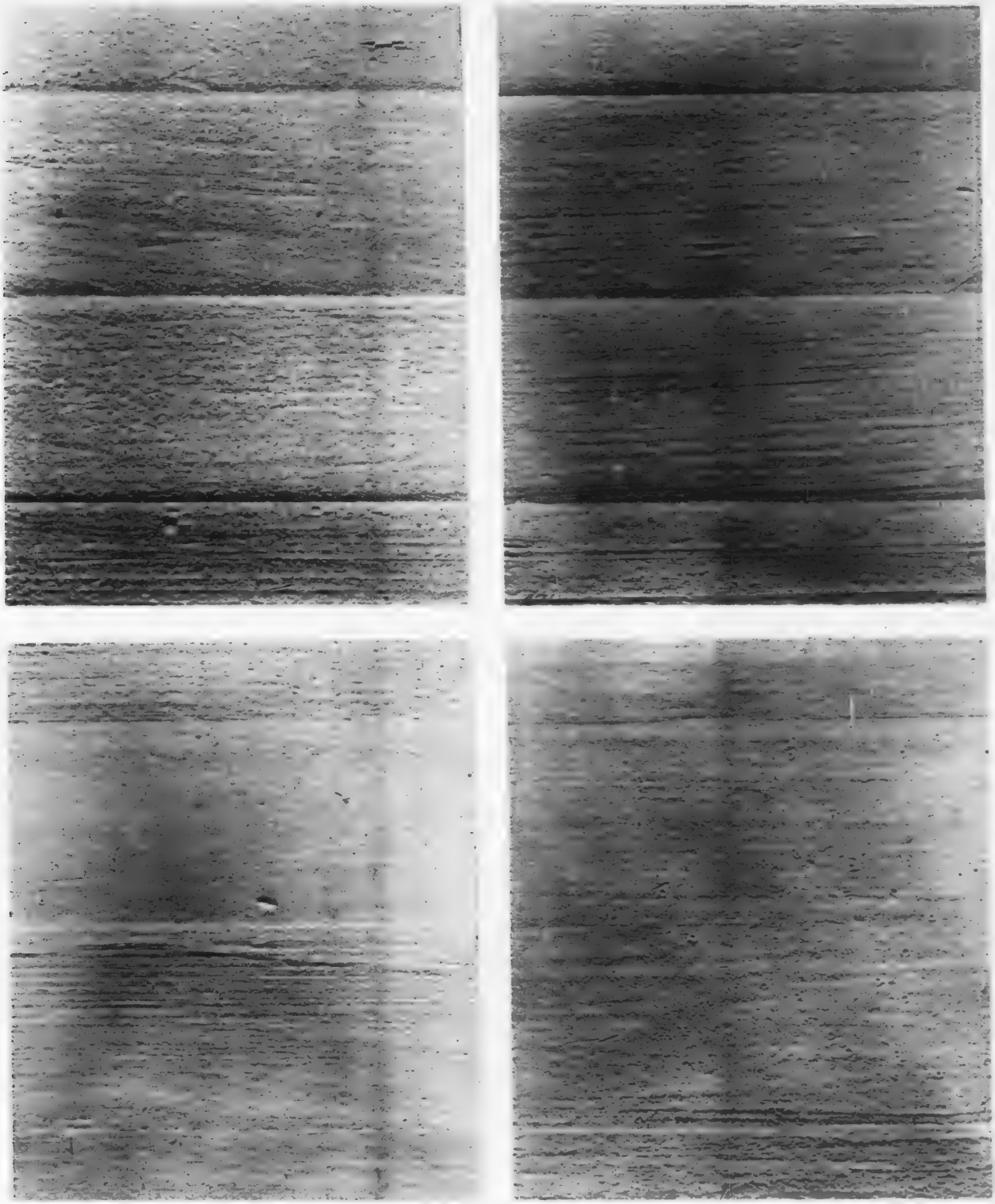

Figure 2.--Yellow-poplar panels, edge-glued with urea resin cured by high-frequency dielectric heating, and with animal glue set at room temperature.

Upper panels (left urea; right animal glue) were surfaced immediately after gluing pressure was released. Lower panels (left urea; right animal glue) were conditioned 7 days at room temperature before they were surfaced.

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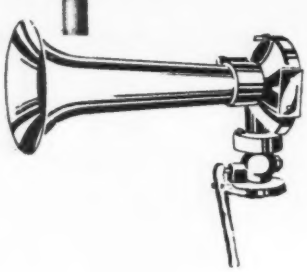

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